INVESTIGATION OF CONVENTIONAL AGGREGATES AND MODIFIED ASPHALT MIXES USING THE MARSHALL METHOD

Part of

PERMANENT DEFORMATION (RUTTING) CHARACTERISTICS OF BINDER-AGGREGATE MIXTURES CONTAINING CONVENTIONAL AND MODIFIED ASPHALT BINDERS

PHASE I

of

COOPERATIVE STUDY WITH THE UNIVERSITY OF CALIFORNIA-BERKELEY AND THE CALIFORNIA DEPARTMENT OF TRANSPORTATION

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DISCLAIMER STATEMENT

TABLE OF CONTENTS

LIST OF TABLES

List of Figures

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Appendix

ABSTRACT

"Permanent Deformation (Rutting) Characteristics of Binder Aggregate Mixtures Containing Conventional Asphalt and Modified Binder" is a joint research project involving University of California, Berkeley and Montana State University (MSU).

The investigation of mixtures containing various binders using the Marshall mix design procedure was conducted in MSU. Based on the 88-89 research on the "Effect of Commercial Modifiers on the Physical Properties of Montana Asphalt", Kraton 4141G and Polybilt copolymer modifiers and Cenex and Conoco asphalts were selected for this research work.

The results of the testing on 1989 asphalts from the same sources gave an opportunity to compare with the 1988 results. The asphalt tests such as penetration at 77°F and 39.2°F and ring and ball tests were carried out to observe the consistency of unmodified and modified asphalts. This proved that a particular asphalt can be modified to give consistent asphalt properties.

The Marshall mix design method involves many variables, such as aggregate gradation, asphalt mix and compaction temperatures, operators and equipment. The variables have definite effects on the results as demonstrated from the results of tests conducted with controlling different variables. Marshall test parameters such as stability and flow, void ratio were not affected by the modifiers significantly while density was lowered to some extent. Experimental design ANOVA analysis indicated that stability and density values were not significantly different for modified and unmodified asphalt. But these values were significantly different for controlled and split aggregate and for 50 and 75 blows compaction.

The impact of Kraton and Polybilt addition to the asphalts, as determined by Marshall stability and flow values at optimum asphalt content, were negligible considering the variation normally observed with this test. Thus, the modification of asphalt binder does not significantly alter the outcome of Marshall mix design procedures.

A deviation in fines (low side) in aggregate gradation from the specification can result in high optimum asphalt content and high void ratio at higher percent of asphalt content. The Marshall mix design can be used for the modified binder, as for any other conventional asphalt, to obtain optimum asphalt content and Marshall test parameter values. However, it is hard to conclude from the observation of the Marshall test results, alone, whether the modified asphalt will improve the permanent deformation characteristics.

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INTRODUCTION

"Permanent Deformation (Rutting) Characteristics of Binder-Aggregate Mixtures Containing Conventional Asphalt and Modified Binders" is a joint research project involving the University of California, Berkeley and Montana State University. The purpose of the project is to study the permanent deformation characteristics of binder-aggregate mixtures containing conventional asphalt and modified asphalt binders subjected to repetitive applications of stresses resulting from increased tire pressure associated with increased truck axle loads and the use of radial tires.

The investigation of mixtures containing various binders using the Marshall mix design procedure was conducted at the Montana State University. The California Stabilometer methodology together with creep and repeated load tests in both the axial and shear modes are being performed at the University of California.

During 88-89, the initial research on asphalt modifiers was performed at MSU ("Effects of Commercial Modifiers on the Physical Properties of Montana Asphalt")(1). It was found that two modifiers, Kraton 4141G from Shell Chemical and Polybilt from Exxon Chemical, improved the asphalt properties to a greater degree than the other modifiers tested. Kraton is a thermoplastic block copolymer rubber, while Polybilt is a copolymer of ethylene vinyl acetate.

In the present study of the mix design, two conventional Montana 1989 asphalts, Cenex (Laurel) and Conoco (Billings), and

four modified asphalts (both asphalts modified with Kraton and Polybilt) were used. The grade of asphalt used was 120/150 penetration. Samples of the same aggregate, conventional asphalt and modified asphalt are being used in the Soil Mechanics and Bituminous Material Laboratory of University of California.

The results of the testing on the 1989 asphalt from the same source gave an opportunity to compare with the results of the 1988 asphalt. Standard asphalt tests were run to check the consistency of the parameter values with those of the 1988 asphalts.

Since Montana State University is using the Marshall method of mix design for the investigation of the modified asphalt, it is appropriate to study the state-of-the art status of the method itself, which has passed several stages of evolution. Current practices of the method were reviewed and discussed.

The mix design procedure has already been established for the conventional asphalt, and the behavior of the asphalt cement is well known. The user and contractor are well versed with the method for conventional asphalt. The modified asphalt is new to the user agencies and contractors and both are skeptical about it. The questions raised in the prebid conference (11/89) at Montana Department of Highway (MDOH), Helena were 1) What are the storage, mixing and compaction temperatures of the modified asphalt? 2) How is it different from the conventional asphalt for storage and use? 3) Will it take greater compaction effort? 4) Where and how is the modifier mixed with the asphalt? 5) Who will

mix the modifier? 6) What are the risks involved in modified asphalt? 7) Who will be responsible for the modified asphalt specification?

The physical asphalt test parameters such as penetration, viscosity and ring and ball softening points are improved greatly by modification of the asphalt. Will this improvement reflect in the mix design parameters and thus reduce rutting problem?

The following section discusses the Marshall method and parameters, materials, methods and procedure, results and conclusions.

MARSHALL METHOD OF MIX DESIGN

The Marshall stability test itself is a type of unconfined compressive strength test in which a cylindrical specimen is compressed radially at a constant rate of strain. The maximum load sustained by the specimen is recorded as the Marshall stability value and the deformation at failure is recorded as the Marshall flow value. Prior to the actual stability tests, unit weight determinations are carried out on the test specimens. The "optimum" binder content then selected for design is essentially a compromise value which meets specified requirements for stability, deformation, void content and maximum unit weight of compacted specimen. Marshall test results for optimum binder content relate to most studies of actual road surface behavior.

The unit weight of the mixture increases with increasing binder content until a maximum value is obtained, after which the

unit weight decreases. At first the binder acts as a lubricant and helps the aggregate particles to slide over each other. Once an optimum amount of binder has been added, it acts only to displace the particles and so unit weight decreases. If a dense mixture is to be obtained, it is important that the amount of binder should not exceed the optimum for the compaction effort applied.

The stability value of the mixture increases with increasing binder content until a maximum value is obtained, after which stability decreases. The combination of the internal friction, provided by the interlocking aggregates, and the cohesion component, provided by the thin viscous bituminous film coating the particles, is maximum stability value at optimum asphalt content.

The flow value increases as the binder content increases. The rate of deformation change is slow at low binder contents but increases rapidly as high binder content are reached. The asphalt surfacing with low flows and high stability will not deform easily but are likely to be brittle, while those with low stability and high flows deform easily under traffic.

The percent of voids in the total mix decreases with increasing binder content until a value is reached at which it begins to level off.(2)

Detailed discussions of this introductory overview are given in the following chapters.

Marshall Method - Background

The Marshall mix design method has been used by highway agencies through out the world to design and control bituminous paving mixtures. At present 76 percent of state highway agencies in the United States use this method. (3)

History: The Marshall procedure as applied to design and control of asphalt mixtures was developed by the Department of Defence during the period from World War II to the late 1950's. The need for a mix design procedure to proportion aggregate and asphalt binders to sustain increasing wheel loads and tire pressure of military aircraft led to the development of a modified Marshall mix design method. Tire pressures increased from 100 psi to 300 psi.

Initially, the Marshall method was developed at the Mississippi Highway Department by Mr. Bruce G. Marshall and was used in the South by several highway agencies. The initial Marshall compaction procedure used 25 blows of a standard Proctor hammer with an application of 5000 pounds static load for two minutes. Several stages of modification on the initial Marshall method has taken place since then. Substantial modification and refinement had taken place during early studies at the USEA Waterways Experiment Station in Vickburg, Mississippi. The study included test sections to evaluate various combinations of asphalt content, aggregate gradation, aggregate type and fillers and their effect on minimum thickness requirements and densities of surfacing.

The Marshall procedure was adopted for the following reasons:

a) " For a given compaction effort, the optimum percent of asphalt can be determined for any mix that will give maximum density, durability and stability.

b) Where a choice of gradation is possible, including mineral filler, the best gradation of the mix can be determined which will give maximum density, durability and stability.

c) A minimum stability value for asphalt mixes can be set which will assume satisfactory performance in actual service.

d) Prompt field control is possible curing construction, therefore pavement can be laid uniformly to specified stability requirements.." (4)

<u>Marshall Method as Practiced by the Montana Department of Highways:</u>

At present, highway agencies in 38 states use the Marshall Mix Design Method in the United States. Being a empirical test method which does not measure the fundamental engineering properties of bituminous concrete, the Marshall Method has had its short-comings despite overall success. This led to its modifications by several different agencies. There are significant differences in the procedure and applications of the Marshall Method among the agencies. (3)

Montana uses 100% passing 3/4, 1/2 inch nominal maximum aggregate size. Both hand and mechanical compacting equipment are used in preparing the Marshall specimen. The compaction used in

preparing the Marshall mold is equivalent to 50 blows of the Marshall hammer. The Rice specific gravity test is conducted to achieve theoretical maximum specific gravity. The effective asphalt content is not used to calculate Voids in the mineral aggregate (VMA) values. The traffic is divided into three different categories in Montana; heavy, medium and light, as shown in Table 1. The required stability values depend on the traffic category. The Marshall parameter values for the three different categories are shown in Table 1.(3)

Table 1. Marshall Parameter Values for Montana Marshall Method.

Traffic	Criteria ADT	Stability(lb)	Flow	% Voids
Heavy	1000	2000 - 3000	8 - 16	2 - 5
Medium	200 - 1000	1500 - 2500	8 - 16	3 - 5
Light	1 - 200	1000 +	8 - 18	4 - 6

The optimum asphalt content is based on the median voids determination.

Marshall Method at Montana State University:

The method and equipment in the Montana State University laboratory are similar to those of the Montana Department of Highways. A molded specimen size of four-inch diameter and two and one half inch height are used, which requires mixing of 1150 grams of aggregate and a predetermined weight of asphalt. A conventional mechanical mixer mixing bowl apparatus is used to mix the mixture for two minutes, after which the mix is

transferred into a preheated mold. The entire process is done according to the AASHTO procedure. Temperature is noted at each stage. The mechanical compactor with the rotating base is used to compact the mold with the specified 50 blows on either side of the mold. A 10 pounds hammer with 18 inches drop is used. The mechanical hammer is not calibrated to a hand operated hammer.

An automatic recorder for the plotting the load/deformation curve during the stability test is used.

Definition and Discussion on Marshall Test Parameters:

Marshall Stability:

Stability has been defined as "resistance to deformation" with an implied emphasis towards resistance to flow or rutting in an asphaltic or soil layer. It is noted that no special unit is given for stability. For asphaltic concrete, the stability definition is broadened by including resistance to tensile, compressive, and shear stresses that cause failure in a pavement surface.(5)

A review of the literature indicates that the Marshall stability value is a measure of tensile strength. Marshall value is affected primarily "by the tensile strength or cohesion properties of a mixture". It would seem to be apparent that the Marshall test does give a measure of tensile strength and that the method's success in preventing shear deformation (rutting) failure comes from the control of aggregate texture and gradation, asphalt content, and compaction. (6)

Asphalt mixes may have to be designed to resist rutting

(accumulation of permanent deformations) under high tire pressure and large numbers of load repetitions. Generally such permanent deformations occur under conditions of low mix stiffness; resistance to permanent deformation under these conditions has been defined as stability. (5)

Mixes must also resist the development of excessive rutting under standing loads and be resistant to shoving from decelerating and accelerating traffic. The requisite resistance to deformation can be defined in the laboratory by some form of triaxial compression test; one definition of stability can be considered as the stress corresponding to a small strain in this type of test. From this definition, the higher the stress at a fixed strain or the strain at a fixed stress level, the greater the mix stiffness.(5)

Resistance to permanent deformation is promoted by using aggregate with rough surface texture, dense gradations, comparatively low asphalt content, harder (stiff) asphalt and well compacted mixtures so long as the air void content does not fall below about three percent.(4)

The Marshall stability test stresses and fails the entire specimen. Definite shear planes divide the specimen into four separate pieces. The stability value is a measure of the resistance of the specimen to the development of internal shear planes. This resistance is considered directly related to the degree to which masses of particles are bounded together mechanically or with bituminous material. (4)

Marshall Flow:

The flow value is considered to measure the plasticity of an asphalt mixture.

Void Ratio:

The amount of voids in and asphalt mixture is the single most important factor that affects performance throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction and additional compaction under traffic.

There has been much work that has shown that the initial in-place voids should be no more than approximately 8 percent and in-place void should never fall below approximately 3 percent during the life of the pavement.(7) High voids lead to permeability of water and air resulting in water damage, oxidation, raveling and cracking. Low voids lead to rutting and shoving of the asphalt mixture. In a study of rutting of asphalt pavements, showed that significant rutting was likely to occur once the in-place voids reached approximately 3 percent.(7)

The initial air voids content is determined by comparing the in place bulk density to the theoretical maximum density for the mix being evaluated. The final in-place air voids are estimated based on the mix design and field quality control testing. The voids obtained during the mix design and laboratory compaction of the samples from construction site is an estimate of the in-place voids after traffic. The number of blows with the Marshall hammer were initially selected to provide voids in laboratory compacted

samples equal to the measured voids after traffic. Hence, the voids determined from laboratory compacted samples are estimate of the final in-place voids.

Density:

The voids in an asphalt mixtures are directly related to density. Thus density must be closely controlled to insure that the voids stay within an acceptable range. One method that has been used to specify density is to require that the in-place material be compacted to some percent of the laboratory density. The standard laboratory density is specified as 50 or 75 blows with the Marshall hammer. Typically, specification will require at least 95 percent of laboratory density in some cases to as much as 98 percent in others. Some specifications do not allow mixes to compacted to a density greater than 100 percent of laboratory density. The mixes are designed to have 4 percent voids, and if compacted to a density greater than 100 percent, premature rutting is likely to occur.

The density produced with a manual hammer has been shown to correlate with density in the field after traffic. Hence any other compaction (mechanical or otherwise) must be calibrated to produce the density equal to that obtained with the hand hammer.

Additional asphalt content must never be added for the sole purpose of reducing the in-place voids. If the in-place voids are too high, assuming the mixture has been properly designed, then more compactive effort must be exerted to decrease in-place voids.(7)

MODEL FOR THE DEFORMATION

A three phase system of asphaltic concrete are comprised of a three dimensional particle skeleton (solid), a viscous mortar material (fluid) and air filled voids (gaseous).

Aside from the viscous matrix, a three-dimensional mineral skeleton is formed during compaction and later under compressive or shear stress. The smaller mineral particles which are not part of the mineral skeleton form the bituminous mortar along with the binder. Both elements, the matrix of bituminous mortar and mineral skeleton resists external loading (stresses).

In soil mechanics, the yield resistance of soil is considered as the sum of internal friction and cohesion. This concept stems from Coulomb's theory.

In asphaltic concrete, the voids in the mineral mix are partly filled with bitumen, which in contrast to water present in soils, has a very high viscosity. Therefore, the deformation resistance resulting from the adhesion of binder and mineral particles as well as the viscosity of binder are highly significant.(8)

According to Nijboer, the entire deformation resistance of bituminous mixes can be explained in terms of three precisely defined quantities, namely:

Total resistance $t = t_i + t_q + t_u$

t_i - initial resistance due to real and apparent cohesion and interlocking of the mineral particles.

t_q - internal friction associated with the bulk density, the shape and size and roughness of the mineral particles as well as the grading of mix.

t_u - viscous resistance due to shear resistance resisting from the viscosity of the bituminous mortar.(9)

MATERIALS

Asphalt

Samples of 120/150 penetration grade asphalt cement were obtained from Cenex Refinery in Laurel and Conoco Refinery in Billings.The two refineries were observed to be the most diverse during the initial modifier study, and thus, were selected for the rutting study. Both asphalts were modified by the manufacturers, as described below, and made available to UC and MSU.

Kraton Modified Asphalt

Kraton rubber-asphalt mixtures were prepared by Shell Development Company utilizing 4.3% and 6% w neat Kraton D4141G. Each make of asphalt, Cenex and Conoco, was modified with the two different percentages of Kraton 4141G polymer. Kraton thermoplastic rubber polymers are a unique class of rubber designed for use without vulcanization. They differ fundamentally in molecular structure from the typical plastic or commercial rubber (homopolymer or random copolymers) in that they are triblock copolymers with an elastomeric block in the center and a thermoplastic block on each end. They are readily soluble and thus are suited to the formulation of solvent-based adhesives.

D4141G is linear SBS (Styrene-Butadiene-Styrene) block copolymers similar in molecular architecture to D1101. "D" designation refers to either SBS or SIS polymers. The first "4" identifies the polymer as containing process oil usually a napthenic/paraffinic type which is added to the polymer to aid in the mixing of the polymer into bitumen and/or to affect desirable changes in the physical properties of the final binder blend. D4141G contains about 29% oil. The designation G refers to the polymer being in the ground "powder" form again for the purpose of decreasing blending time.

Polybilt Modified Asphalt

Polybilt is an EVA, Ethylene Vinyl Acetate, resin, and encompasses a large family of petrochemical polymers and polymer concentrates designed for asphalt modification by Exxon Chemical Company. Two polymers were used, Polymer 2 and Polymer 7; both are EVAs but differ in molecular weight and VA content. Polymer 2 was used for the asphalt from Cenex, and Polymer 7 for Conoco, at treat rate of 4% and 3.5% by weight, respectively. The reason for the different polymer for Conoco was because it exhibited more synergy with Polybilt than Cenex.(1)

AGGREGATE

Selection of the aggregate was done after conferring with the MDOH materials personnel in Helena and Billings. Since much of the rutting problems in Montana are in the eastern areas and involve Yellowstone River gravel, a representative of YR grave; was chosen. The Billings District provided material from the E.

E. St. John pit. The samples were obtained from stock piles of MDOH, and submitted in several sacks of three fractions, coarse, crushed fine and natural fine; a composite sample was formed utilizing 45%, 40% and 15% portion respectively in accordance with MDOH laboratory report. Standardization of Marshall procedures required careful attention to representative splitting of the composite sample of about 1150 gm.

Each time the aggregate was split, a sample was taken and a sieve analysis was run. The representative aggregate gradation curve was drawn from the mean of 9 such samples. It was observed that all the gradations confirmed within the band of acceptable level of gradation except for the minus # 200 sieve. The minus # 200 sieve was consistently low at 2.5% instead of 6% as specified. The average values of the result of the sieve analysis along with the specification for the plant mix surfacing aggregate grade B is shown in the Table 2. The aggregate gradation curve along with the specification band is shown in the Figure 1.

The recommended portions of the coarse, crushed fine and the natural fine were mixed to give the actual mix in the field. The split sample from the mix gives us the representative sample of the aggregate in the plant mix. All the test specimens made with the split sample from the mix of the recommended portion of 45% coarse, 40% crushed fines and 15% natural fine are low in the minus # 200 size fines.

The Marshall mix design from this sample gives us the

Table 2. Mean Values of the Aggregate Gradation of Splited Aggregate.

Size Sieve	% Passing Mean	% Passing Standard Deviation	Specification Limit Maximum	Median	Minimum
3/4"	100			100.00	
1/2"	87.89	3.66	93.00	86.00	79.00
3/8"	72.01	4.58	82.00	75.00	68.00
# 4	53.47	4.63	60.00	53.00	46.00
# 10	36.11	3.31	43.00	37.00	31.00
# 40	17.00	1.90	23.00	18.00	13.00
# 200	2.56	.055	7.50	6.00	4.50

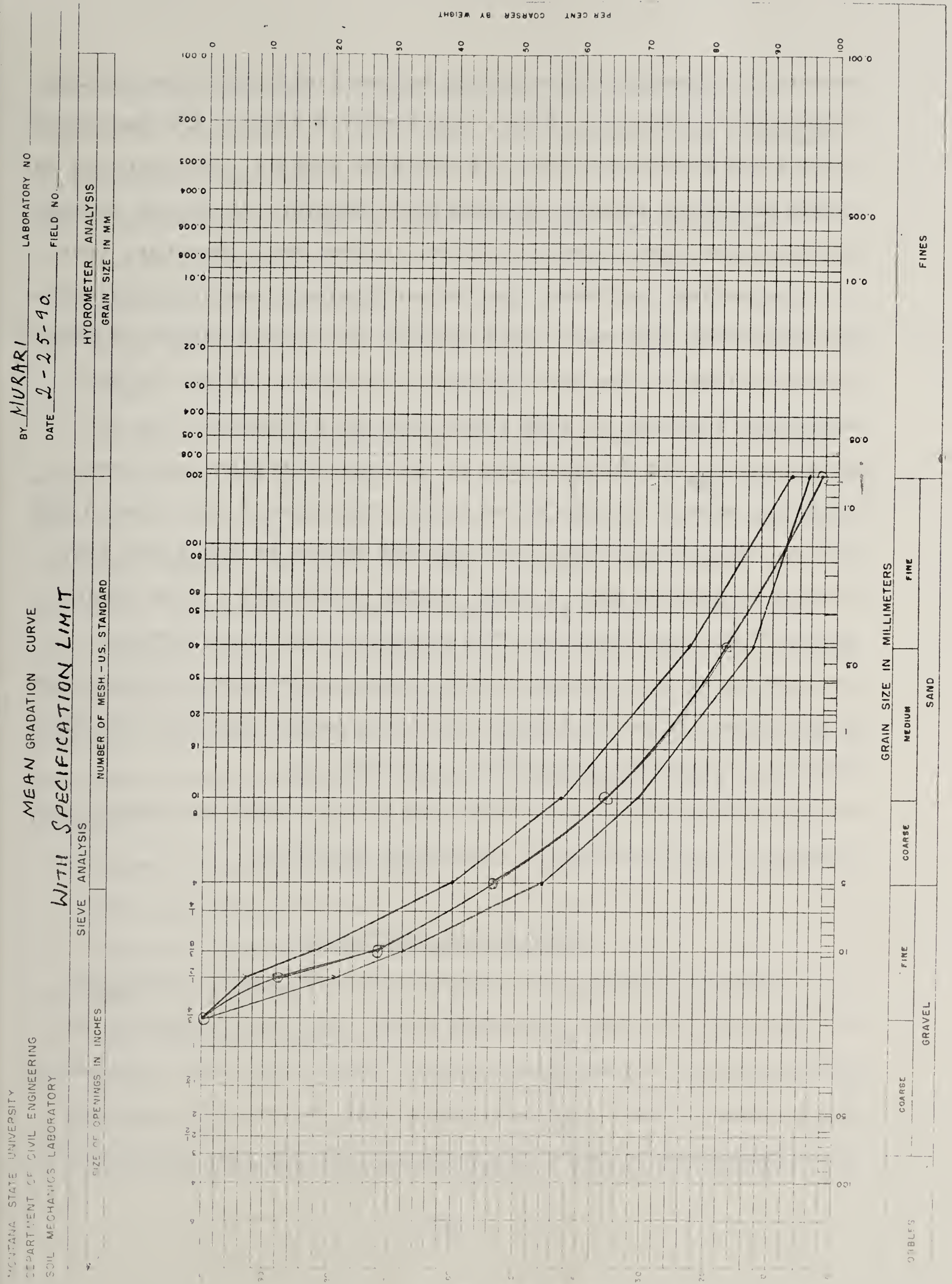

Figure 1. Mean Gradation Curve of Split Aggregate

Marshall parameter values closer to the field condition, without hydrated lime mineral filler. The Marshall test on the aggregate-binder mix with unmodified and modified asphalt were carried out using the split samples of aggregate. However, it failed to meet the required specification arrived at from the laboratory test.

Repeating the tests, the proportionately combined aggregate was separated into each sieve size of the specification to obtain median values of the specification. The median values of the aggregate retained in each sieve size were obtained. The mix representing the median value of the specification was mixed manually except for the minus # 200. The minus # 200 size in the mix was determined. Then the required amount of the minus #200 size was added to make a mixed sample confirming to the median size of the specification. The aggregate blend combination conforming to the gradation requirement of the specification was prepared according to Asphalt Institute Manual Series No.2 (MS2) Appendix. Gradation Analysis of Aggregate.(9)
The results obtained from both type of mix, split and controlled aggregate are discussed in subsequent sections.

METHODS AND PROCEDURES

Standard asphalt tests such as penetration at 39.2°F and 77°F and ring and ball softening point tests were conducted on the unmodified and modified asphalt. These tests were repeated on the residue of thin film oven tests. The purpose of conducting these tests was to check the conformity of the test parameter of

the materials received in 1989 with that of 1988 batch of materials. The results of the tests are presented and discussed in subsequent sections.

The total number of asphalt tests conducted are as follows:

Penetration at 77°F	144
Penetration at 39.2°F	144
Ring and Ball	32
Total	320

Similarly, fifteen Marshall specimens (three specimen per asphalt content of 5%, 5.5%, 6%, 6.5% and 7%) were molded for each of the unmodified and Polybilt, 4.3% Kraton and 6% Kraton modified asphalts (4.3% Kraton and 6% Kraton are written as Kraton-4.3 and Kraton-6 respectively). The Marshall test for stability and flow, bulk specific gravity, Rice specific gravity and percentage air void determination were conducted on each specimen. The raw test results are presented in the Appendix A. The total number of Marshall tests and parameter tests are as follows:

Marshall Test Specimen Mold	258
Bulk Specific Gravity	258
Marshall Stability	258
Marshall Flow	258
Rice Specific Gravity	258
Total	1290
Grand total	1620

The test property curves for hot-mix design by Marshall

method are shown in Appendix B. The optimum asphalt content for each of the modified and unmodified asphalts was computed from the curves. The data obtained for optimum asphalt content and test parameter values at optimum asphalt content are shown and discussed in subsequent sections.

Procedure

The AASHTO standard method of test procedure was followed in conducting the Marshall Mix Design Method and related tests. The AASHTO test number and test title are as follows:

AASHTO Designation	Test Title
T11 - 82	Amount of Material Finer Than 0.075mm (# 200) Sieve in Aggregate.
T27 - 82	Sieve Analysis of Fine and Coarse Aggregate.
T49 - 80	Penetration of Bituminous Material.
T53 - 81 in	Softening Point of Asphalt (Bitumen) and Tar Ethylene Glycol (Ring & Ball).
T166 -78(1982)	Bulk Specific Gravity of Compacted Bituminous Mixtures.
T179 - 80	Effect of Heat and Air on Asphalt Materials (Thin Film Oven Test).
T209 - 82	Maximum Specific Gravity of Bituminous Paving Mixtures.
T245 - 82	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.
T248 -74(1982)	Reducing Field Samples of Aggregate to Testing

Size.

T269 - 80 Percent Air Voids in Compacted Dense nd Open Bituminous Paving Mixtures.

Discussion Of Procedure:

There are many variables associated with the Marshall mix design. First among the variables are the constituents of the mix, that is the aggregate and asphalt. Other variables are the mix temperature and those associated with human factor, operator, laboratory and testing equipment. Precision and quality control factors are important. The Marshall method of mix design consists of long procedures, starting from the aggregate gradation, mixing of asphalt and aggregate, making of the molds, cooling of molded specimen, and extraction of the specimen from the mold using a hydraulic jack. In each step, temperature of aggregate and asphalt and mix temperature before compaction is important. As discussed earlier, the type of equipment used is important. After the mold is produced, each molded specimen goes through the number of tests, such as bulk specific gravity, involving the water bath temperature, time in the water bath, precision of weighing the sample in water and air.

Marshall stability and flow test are carried out on the stability test machine. Each Marshall specimen is immersed in the water bath at 140°F for 30 to 40 minutes. The precision of the bath temperature and duration in the water bath and the time of completing the whole test within 30 seconds on each specimen may not be exact. There are possibilities of not exacting the

processes thus error may be introduced.

The Rice specific gravity test is carried out on the crumbled specimen after 3 minutes in the microwave oven. The specimen is separated, as far as possible, by breaking the mold with a spatula. Each specimen is weighed in the flask and subjected to the vacuum for 15 minutes, shaking every two minutes. The possibilities of error are over heating in the microwave oven or not separating the particles or breaking the stone.

When asphalt concrete mix specimens are compacted in a given compactor, differences in the compaction temperature and the actual preparation of the specimens can significantly influence the test results. Clearly, these are operator related variables. (10)

Again, operator related factors, such as conditioning of specimen and the duration of the actual testing process were cited as sources of differences between test results.

Georgia,s criteria requires a review of the procedure or equipment, or both, if a laboratory average exceeds the following ranges when compared with the overall average

Density: + - 1.5 pcf (0.024 gm/cc)

Stability: + - 400 and

Flow: + - 0.02 inch.

The results obtained from the Georgia studies tend to support that discrepancies in Marshall test results are due to both equipment and technician related factors. (10)

In 1979 a Marshall equipment correlation study was conducted by the Utah Department of Transportation. The objective of the investigation was to study the variability that resulted from using different technicians and equipment. It was evident from a comparison of the values for range and standard deviation that operator and equipment have a significant effect on the test result.

In the Canadian studies, it was concluded that there can be significant variability in Marshall test results and that this variability can be attributed to operator as well as equipment variability.(10)

At Montana State University, the Marshall test was conducted by the students working part time and a graduate student. It was a learning experience for the students. The performance of each student follows the learning curve which could reflect on the test results. It is natural to expect some variation and error in the result.

<u>Mixing and Compaction Temperature</u>

According to the Asphalt Institute, there are certain binder viscosities that should be used for optimum mixing (170 Centistoke) and compaction (280 Centistoke) of asphalt concrete mixtures. The Polymer modification produced significant increases in the 275°F viscosity of the original asphalt.

In order to assure suitable mixing and adequate compaction time, it may be necessary to increase the plant temperature. Field experience with the additives studied herein has shown that

the increase in temperature is necessary to achieve good compaction; however, optimum mixing and compaction temperatures are not simply a function of the viscosity of the binder when asphalt additives are used. These optimum temperatures need to be determined. Viscosity - temperatures data for these modified binders can be used as a guide; but, apparently, only field experience can be used to make final decisions.(11)

Since the Marshall method of mix design requires that the asphalt be within specified viscosity ranges during mixing and compaction, it may be necessary to adjust the mixing and compaction temperatures while conducting laboratory work. Field experience with Kraton rubber modified asphalt, however, shows no unusual difficulties when processing and compacting the hot mix asphalt concrete produced with this higher viscosity binder.(12)

Kraton rubber modification of asphalt binder does not significantly alter the outcome of Marshall mix design procedure. Adjustments in optimum binder content may be necessary, but the magnitude of these adjustments are not unusual compared to those normally used with different viscosity grades of asphalt. The impact of Kraton rubber additives as determined, by Marshall stability and flow values, is negligible considering the variations normally observed with this test.(12)

TEST RESULTS AND OBSERVATIONS

From observation of the asphalt test results, Table 3, it is found that the results of the test parameters are improved to

1989 Asphalt

Table 3. Asphalt Test On 1989 Modified and Unmodified Asphalts.

Tests	Cenex Unmodified	Kraton (4.3%) Modified Cenex	Kraton (6%) Modified Cenex	Polybilt Modified Cenex	Conoco Unmodified	Kraton (4.3%) Modified Conoco	Kraton (6%) Modified Conoco	Polybilt Modified Conoco
Ring and Ball Softening Pt.	109.50	148.50	167.00	134.00	110.00	136.50	182.50	161.00
Penetration at 39.2 F	48.00	54.10	38.83	41.60	41.20	45.60	37.56	33.90
Penetration at 77 F	137.50	92.20	77.20	95.90	140.00	101.00	85.56	68.20
Thin Film Oven Test	0.134	0.091	0.106	0.092	0.043	0.050	0.069	0.004
After TFOT								
Ring and Ball Softening Pt.	117.50	129.00	168.00	134.00	116.50	134.50	176.50	146.50
Penetration at 39.2 F	30.00	49.00	28.20	29.30	37.67	49.40	20.10	27.30
Penetration at 77 F	85.30	79.70	61.56	60.20	95.20	85.40	66.30	52.40

different degrees, as expected. The word "improvement" is used to indicate that the parameter values are in favor of the betterment of the permanent deformation (rutting) characteristics. The values of the ring and ball softening point of the modified asphalt are higher than those of the unmodified asphalt, indicating improvement in high temperature susceptibility. The penetration values at 39.2°F and 77°F of the modified asphalt are low compared to those of the unmodified asphalt. The values for the ring and ball softening point of the Polybilt modified Conoco for both before and after thin film oven test could not be obtained because the film of asphalt coating the ball breaks up before the ball reached the bottom plate. The test was repeated until right results were obtained. The asphalt film cracked when the ball reached bottom plate, however, the ball did not come out of asphalt film.

Comparison of the Test Result of Parameters Between 1989 and 1988 Tests:

The asphalts received in 1989 from Cenex and Conoco were tested for consistency of test parameter values with that of 1988 test parameter. Both asphalts were modified with the same percent of Polybilt (4% of Polymer 2 for Cenex and 3.5% of Polymer 7 for Conoco) as was mixed with the 1988 asphalts. Again, both the asphalts were modified with 4.3% Kraton and 6% Kraton.The comparison of test results is demonstrated in the Table 4.

It is observed from Table 4 that there is little difference in the penetration at 39.2°F and 77°F and the ring and ball

Table 4. Comparison of Test Results Between 1988 and 1989 120/150 Asphalts.

Asphalt	Cenex Unmodified		Kraton Modified Cenex			Polybilt Modified Cenex		85/100 Cenex
			4.3%	6%	6%			
	1989	1988	1989	1989	1988	1989	1988	1988
Ring and Ball Softening Pt.	109.50	114.80	148.50	167.00	163.40	134.00	133.70	116.60
Penetration at 39.2 F	48.00	42.00	54.10	38.83	37.00	41.60	39.00	24.00
Penetration at 77 F	137.50	137.00	92.20	77.20	79.00	95.90	91.00	89.00
Thin Film Oven Test	0.134		0.091	0.106		0.092		
After TFOT								
Ring and Ball Softening Pt.	117.50	116.50	129.00	168.00	162.50	134.00	137.30	124.70
Penetration at 39.2 F	30.00	31.00	49.00	28.20	35.00	29.30	29.00	29.00
Penetration at 77 F	85.30	85.00	79.70	61.56	64.00	60.20	59.00	54.00
Marshall Stability	2193.00	2400.00	2023.00	2335.00	3500.00	2200.00	2330.00	2480.00
Marshall Flow	12.13	14.00	13.25	13.20	15.20	14.15	16.40	13.00
Density (Unit Weight)	2.351	2.387	2.327	2.337	2.370	2.342	2.383	2.332
Percent Void Ratio	2.83	3.00	4.20	3.10	3.80	3.58	3.00	3.50

Asphalt	Conoco Unmodified		Kraton Modified Conoco			Polybilt Modified Conoco		85/100 Conoco
			4.3%	6%	6%			
	1989	1988	1989	1989	1988	1989	1988	1988
Ring and Ball Softening Pt.	110.00	113.00	136.50	182.50	179.60	161.00	158.90	120.20
Penetration at 39.2 F	41.20	40.00	45.60	37.56	36.00	33.90	34.00	30.00
Penetration at 77 F	140.00	133.00	101.00	85.56	82.00	68.20	80.00	92.00
Thin Film Oven Test	0.043		0.050	0.069		0.004		
After TFOT								
Ring and Ball Softening Pt.	116.50	118.40	134.50	177.00	176.90	146.50	149.00	121.10
Penetration at 39.2 F	37.67	31.00	49.40	20.10	39.00	27.30	26.00	19.00
Penetration at 77 F	95.20	94.00	85.40	66.30	67.00	52.40	62.00	68.00
Marshall Stability	1846.00	2060.00	2336.00	2638.00	2418.00	2112.00	2640.00	2680.00
Marshall Flow	10.58	8.40	12.80	14.80	15.00	13.04	13.60	13.60
Density (Unit Weight)	2.353	2.388	2.348	2.345	2.373	2.336	2.376	2.361
Percent Void Ratio	2.89	3.60	3.14	2.10	3.00	3.79	3.20	3.10

results in both the before and after thin film oven test on unmodified asphalt Cenex and Conoco. The same kind of observation is made in Polybilt modified Cenex and Conoco except for the penetration value of Polybilt modified Conoco at 77°F. However, great differences in the 4.3% Kraton 4141G modified asphalt in all test parameter values were observed. This is expected, as the percentage of Kraton 4141G was low. There were not much difference between the 1988 asphalt and 1989 asphalt modified with 6% Kraton 4141G polymer. This gave us an opportunity to see the effect on parameter values as a function of the percentage of modifier used. Thus, we might be able to obtain the desired properties by changing the percent of modifier used.

On comparison of the results of Marshall mold specimen tests, it is observed that the optimum percent of asphalt content in 1989 is increased by almost 1 percent in most of the cases from that of 1988. This may be because of the fact that the tests in 1988 were limited to tests on 5%, 5.5%, 6%, and 6.5% asphalt content. The maximum percent of asphalt content was only 6.5%. Percent air void at optimum asphalt content remains close to 4% in both the 1988 and 1989 results. The comparisons are made with the tests on split aggregate. Other parameter values, such as unit weight, Marshall flow and stability are low compared to that of 1988 values, as can be seen from the Table 4. Other variables between the 1988 and 1989 tests involved the operators.

RESULTS

The sequence of Marshall mix design tests was conducted with

differences in variables. The first set of tests was conducted with a representative sample of split aggregate depicting the actual mix in the field. The representative sample was obtained by splitting the aggregate mix into a sizes of about 1150 gm each. The tests were conducted in blocks, each of which consisted of three samples at a set percent (5%, 5.5%, 6%, 6.5%, and 7%) of specified asphalt (modified or unmodified). The fifteen test specimens (3*5) for each asphalt were made, and parameter tests were completed before other sets of tests were carried out. The Marshall mixing and compaction temperature for the modified asphalt were also set at the same as that of unmodified asphalt based on the viscosity of unmodified asphalt.

<u>First Case:</u>

The temperature of the aggregate for the first set of tests was set at 300 - 310°F. The asphalt temperature was set at 265 - 275°F. However it was noted that the modified asphalt needed to be maintained at or above 275°F to maintain smooth flowing. All tests were conducted at 50 blows of compactive effort. The first set of tests was limited to two modified asphalts, Polybilt and Kraton-4.3, and each of the unmodified asphalt. The Kraton-6 modified asphalt had not been received at the time.

The result of the first test is presented in the Table 5 and Table 7 for Cenex and Conoco groups of asphalt, respectively. The Marshall mix property curves were drawn and represented in the Appendix B Cenex and Conoco groups of asphalt.

Table 5 shows the mean and standard deviation for the

Table 5. Results of Marshall Test Parameters of 1989 Asphalts.

Tests	Cenex - Unmodified I					
Asphalt Content	4.50%	5.00%	5.50%	6.00%	6.50%	7.00
Mean Marshall Stability	1463.00	1066.50	1626.00	1828.00	1870.00	1461.00
Standard Deviation	344.00	271.00	460.00	234.00	138.00	162.00
Mean Marshall Flow	10.67	11.00	10.67	11.30	14.33	10.00
Standard Deviation	0.58	2.64	2.08	1.53	2.31	1.00
Mean Bulk Sp. Gravity	2.265	2.288	2.288	2.301	2.329	2.319
Standard Deviation	0.026	0.006	0.017	0.020	0.013	0.018
Rice Specific Gravity	2.514	2.496	2.485	2.476	2.444	2.429
Void Ratio	9.87	8.37	7.90	7.10	4.70	3.33
VMA	17.35	16.94	17.38	17.35	16.79	17.59
Tests	Polybilt Modified Cenex I					
Mean Marshall Stability		2492.00	2842.00	2367.00	2901.00	2164.00
Standard Deviation		225.00	168.00	407.00	389.00	46.00
Mean Marshall Flow		12.33	12.33	11.33	14.33	13.33
Standard Deviation		0.58	1.53	1.53	2.08	3.06
Mean Bulk Sp. Gravity		2.306	2.327	2.318	2.369	2.357
Standard Deviation		0.014	0.023	0.012	0.003	0.003
Rice Specific Gravity		2.474	2.447	2.432	2.397	2.398
Void Ratio		6.76	4.92	4.67	1.17	1.73
VMA		16.29	15.97	16.74	15.36	16.24
Tests	Kraton (4.3%) Modified Cenex I					
Marshall Stability		2062.00	2297.00	2168.00	2741.00	2686.00
Standard Deviation		449.00	337.00	451.00	442.00	180.00
Mean Marshall Flow		11.00	11.67	12.33	13.67	14.67
Standard Deviation		2.00	2.31	2.08	1.53	2.31
Mean Bulk Sp. Gravity		2.426	2.316	2.299	2.316	2.339
Standard Deviation		0.020	0.003	0.015	0.010	0.003
Rice Specific Gravity		2.493	2.472	2.456	2.429	2.408
Void Ratio		8.33	6.33	6.40	4.60	2.86
VMA		11.93	16.37	17.42	17.25	16.88

stability, the flow and density and void ratio and void in mineral aggregate (VMA). Following the criteria set by Georgia, it is observed that from Table 5 that the standard deviation of stability for each percent of asphalt is under 400 except for unmodified Cenex at 5.5%, for Polybilt modified Cenex at 6%, and for Kraton-4.3 modified Cenex at 5%, 6%, and 6.5%. Similarly, the standard deviation of Marshall flow exceeds 2 (.02 inch) in most of the cases of modified and unmodified Cenex. The standard deviation for density is under 0.024 gm/cc in most of the cases. In comparing the Marshall parameter values of the unmodified and modified Cenex, the modified values are higher than the unmodified values. It is observed that the VMA values did not follow any pattern.

From Table 6 for the optimum asphalt content for the Cenex group of asphalt, it is observed that optimum asphalt content changed by 0.76% between the highest and lowest values (Cenex and Polybilt). Asphalt content is high for both modified and unmodified asphalt.

Table 7 shows the results of the first set of tests of modified and unmodified Conoco. The standard deviation of the Marshall stability is above 400 in most of the asphalt contents for both modified and unmodified Conoco [6.5% and 7% of Conoco, 5.5% and 6% of Polybilt modified Conoco and 5.5% of Kraton-4.3 modified Conoco]. Similarly, the standard deviation of the unit weight is also above 0.024 gm/cc. The VMA values show the raising pattern with the asphalt content.

1989 Asphalt

Table 6. Optimum Asphalt Content for Asphalt Mix Based on Test Property Curves for First Case.

Asphalt	Cenex	Kraton (4.3%) Modified Cenex	Kraton (6%) Modified Cenex	Polybilt Modified Cenex	Conoco	Kraton (4.3%) Modified Conoco	Kraton (6%) Modified Conoco	Polybilt Modified Conoco
Marshall Stability	6.50%	6.60%		6.50%	6.00%	7.00%		5.50%
Unit Weight	6.50%	7.00%		6.50%	6.00%	7.00%		6.50%
Percent Air Void	6.50%	6.60%		6.25%	6.00%	6.20%		5.56%
Optimum Asphalt Conten	6.50%	6.70%		6.42%	6.00%	6.70%		5.85%
Test Parameter Values at Optimum Asphalt Content								
Marshall Stability	1900.00	2750.00		2720.00	1872.00	2630.00		3076.00
Marshall Flow	12.30	12.90		12.00	11.00	15.30		14.44
Bulk Specific Gravity	2.336	2.337		2.356	2.364	2.347		2.343
Percent Air Void (%)	3.90	3.70		4.10	4.00	1.60		3.25

1989 Asphalt

Table 7. Results of Marshall Test Parameters of 1989 Asphalts.

Tests	Conoco - Unmodified I				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability	1312.00	1546.00	1870.00	1739.00	1672.00
Standard Deviation	183.00	48.00	336.00	475.00	436.00
Mean Marshall Flow	10.30	10.30	12.30	12.00	14.00
Standard Deviation	0.58	0.58	1.53	1.00	1.00
Mean Bulk Sp. Gravity	2.304	2.288	2.364	2.318	2.334
Standard Deviation	0.032	0.005	0.013	0.034	0.002
Rice Specific Gravity	2.503	2.468	2.439	2.434	2.396
Void Ratio	7.97	7.27	3.10	5.00	2.60
VMA	16.36	17.38	15.09	17.18	17.06

Tests	Polybilt Modified Conoco I				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability	2904.00	3133.00	2934.00	2990.00	2687.00
Standard Deviation	72.00	437.00	557.00	234.00	127.00
Mean Marshall Flow	12.00	15.00	14.67	17.33	16.33
Standard Deviation	0.00	1.00	1.15	1.53	2.52
Mean Bulk Sp. Gravity	2.304	2.334	2.328	2.368	2.357
Standard Deviation	0.005	0.016	0.025	0.015	0.011
Rice Specific Gravity	2.461	2.433	2.430	2.411	2.394
Void Ratio	6.53	4.09	4.20	1.80	1.57
VMA	10.66	12.14	12.72	13.86	14.92

Tests	Kraton (4.3%) Modified Conoco I				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability	2646.00	2005.00	2246.00	2634.00	2675.00
Standard Deviation	14.00	620.00	38.00	557.00	238.00
Mean Marshall Flow	19.33	12.33	13.67	13.33	16.30
Standard Deviation	6.03	1.53	2.08	1.15	1.15
Mean Bulk Sp. Gravity	2.328	2.283	2.298	2.349	2.363
Standard Deviation	0.019	0.023	0.015	0.006	0.011
Rice Specific Gravity	2.470	2.466	2.470	2.417	2.377
Void Ratio	5.73	7.40	6.90	2.80	0.60
VMA	10.34	10.95	11.28	13.65	15.53

On observation of the property curves of the Marshall parameter tests in Appendix B, it is observed that the points in the graph form two humps, signifying the possibility of two maximum points. It is noted that the deviation of the point from the smooth curves are those with standard deviations higher than 400 for stability and 0.024 for density in most of the cases.

Second Case:

The second case of the tests were conducted under similar conditions as the first case, that is, split aggregate, and temperature range 300 - 310°F. The only difference is that the second set of tests were conducted within a relatively short period of time, and the operators were more experienced.

Table 8 shows the mean and standard deviation of the test results of Cenex and modified Cenex. Cenex was modified with 4.3% of Kraton and 6% of neat Kraton [written as Kraton-4.3 and Kraton -6] and Polybilt. This resulted in four different test sets. The standard deviation of the Marshall stability exceeds 400 for 5% and 7% Cenex, 5.5% Polybilt and 6.5% Kraton-6 modified Cenex. The standard deviation for Marshall flow was below 2 (.02 inch) in most of the cases. The standard deviation for the density remained under 0.024 gm/cc in all cases except for 5% and 6% Polybilt modified Cenex. It is also observed from Table 8 that the stability value did not vary greatly between the different asphalt contents. The difference between the highest stability at 6% Cenex and least stability at 7% asphalt content of unmodified Cenex is 312. Similar trends were observed in the case of

Table 8. Results of Marshall Test Parameters of 1989 Asphalts.

Tests	Unmodified Cenex II				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability	2469.00	2548.00	2695.00	2625.00	2383.00
Standard Deviation	440.00	45.00	159.00	132.00	469.00
Mean Marshall Flow	10.67	12.33	12.33	12.67	13.67
Standard Deviation	1.15	2.08	1.15	1.53	1.53
Mean Bulk Sp. Gravity	2.341	2.314	2.369	2.363	2.362
Standard Deviation	0.011	0.009	0.004	0.023	0.013
Rice Specific Gravity	2.472	2.461	2.452	2.421	2.412
Void Ratio	5.27	5.94	3.39	2.41	2.06
VMA	10.26	11.13	11.93	13.50	14.29
Tests	Polybilt Modified Cenex II				
Mean Marshall Stability	2311.00	2632.00	2416.00	2476.00	2395.00
Standard Deviation	360.00	429.00	293.00	290.00	178.00
Mean Marshall Flow	10.00	14.00	14.00	14.67	14.67
Standard Deviation	1.00	2.65	1.73	1.15	1.15
Mean Bulk Sp. Gravity	2.298	2.328	2.316	2.367	2.335
Standard Deviation	0.038	0.015	0.027	0.006	0.014
Rice Specific Gravity	2.479	2.438	2.452	2.409	2.411
Void Ratio	7.30	4.51	5.52	1.75	3.14
VMA	10.01	11.96	11.93	13.93	14.32
Tests	Kraton (4.3%) Modified Cenex II				
Mean Marshall Stability	2531.00	2386.00	2674.00	2922.00	2742.00
Standard Deviation	214.00	144.00	234.00	81.00	136.00
Mean Marshall Flow	12.67	12.00	14.67	14.00	16.33
Standard Deviation	1.15	1.00	1.15	0.00	1.53
Mean Bulk Sp. Gravity	2.341	2.343	2.366	2.355	2.372
Standard Deviation	0.014	0.012	0.010	0.005	0.006
Rice Specific Gravity	2.456	2.437	2.430	2.404	2.442
Void Ratio	4.69	3.84	2.62	2.05	2.82
VMA	10.84	12.00	12.72	14.11	13.22
Tests	Kraton 6% Modified Cenex II				
Mean Marshall Stability	1655.00	1960.00	2516.00	2521.00	2297.00
Standard Deviation	141.00	169.00	232.00	473.00	391.00
Mean Marshall Flow	12.00	16.33	11.33	12.33	14.33
Standard Deviation	1.00	2.89	0.58	0.58	3.51
Mean Bulk Sp. Gravity	2.279	2.302	2.333	2.339	2.335
Standard Deviation	0.017	0.015	0.004	0.005	0.018
Rice Specific Gravity	2.471	2.453	2.432	2.401	2.406
Void Ratio	7.77	6.17	4.06	2.56	2.96
VMA	10.30	11.42	12.65	14.22	14.50

Table 9. Optimum Asphalt Content for Asphalt Mix Based on Test Property Curves Data.
Test Second Case.

Asphalt	Cenex	Kraton (4.3%) Modified Cenex	Kraton (6%) Modified Cenex	Polybilt Modified Cenex	Conoco	Kraton (4.3%) Modified Conoco	Kraton (6%) Modified Conoco	Polybilt Modified Conoco
Marshall Stability	6.00%	6.50%	6.50%	5.50%	5.50%	5.50%	7.00%	6.00%
Unit Weight	6.00%	7.00%	6.50%	6.50%	6.50%	5.50%	7.00%	6.00%
Percent Air Void	5.63%	5.19%	6.00%	5.90%	5.46%	5.27%	6.00%	6.07%
Optimum Asphalt Content	5.88%	6.23%	6.33%	5.97%	5.82%	5.42%	6.67%	6.02%
Test Parameter Values at Optimum Asphalt Content								
Marshall Stability	2678.00	2857.00	2453.00	2578.00	2643.00	3000.00	2325.00	3088.00
Marshall Flow	12.31	13.20	11.58	14.06	12.75	12.80	13.65	12.47
Bulk Specific Gravity	2.367	2.362	2.335	2.346	2.366	2.372	2.343	2.350
Percent Air Void (%)	3.50	2.43	3.67	3.78	3.27	3.45	3.33	4.03

modified Cenex also. This shows the sensitivity of stability with asphalt content.

From Table 9 for the optimum asphalt content, it is observed that the optimum asphalt remained around 6% asphalt [5.88 for unmodified Cenex and 6.22, 6.33 and 5.97 for Kraton-4.3, Kraton-6 and Polybilt modified Cenex]. The Marshall parameter values at optimum asphalt content did not vary much from unmodified Cenex; for Kraton-4.3 modified Cenex it was high, and for the other modified Cenex was lower than unmodified Cenex. Similar observations were noticed in the case of the Marshall flow. The lowest density was 2.335 for Kraton-6 and the lowest void ratio was 2.43% for Kraton-4.3.

Table 10 shows the Marshall parameters for modified and unmodified Conoco. The standard deviation of the Marshall stability exceeds 400 only at 7% Conoco and 5% Kraton-4.3 modified Conoco. However, standard deviation of the Marshall flow values were 2.52 for 5% Conoco, 2.08, 2.13 for 5.5% and 7% Polybilt, 2.5 and 2.08 for 5% and 6.5% Kraton-4.3, and 2.52 for 7% Kraton-6 modified Conoco, which exceeded 2 (.02 inch) value. The standard deviation of the density remained within acceptable levels of 0.024 except for 5% Conoco, 6.5% Polybilt, and 5% Kraton-4.3 modified Conoco. The difference of highest and lowest stability between the asphalt content was high. It was 815 for Conoco, 820 for Polybilt, 983 for Kraton-4.3, and 1172 for 6% Kraton-6. This showed that the stability values were sensitive to asphalt content.

Table 10. Results of Marshall Test Parameters of 1989 Asphalts.

Tests	Unmodified Conoco II				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability	2199.00	2677.00	2565.00	2420.00	1862.00
Standard Deviation	352.00	170.00	221.00	265.00	425.00
Mean Marshall Flow	10.33	12.33	13.00	14.00	13.00
Standard Deviation	2.52	0.58	1.00	2.00	1.00
Mean Bulk Sp. Gravity	2.322	2.368	2.364	2.374	2.356
Standard Deviation	0.025	0.013	0.013	0.002	0.009
Rice Specific Gravity	2.476	2.453	2.441	2.418	2.414
Void Ratio	6.23	3.45	3.15	1.82	2.42
VMA	10.12	11.42	12.32	13.61	14.21
Tests	**Polybilt Modified Conoco II**				
Mean Marshall Stability	3002.00	3082.00	3146.00	2647.00	2326.00
Standard Deviation	160.00	224.00	158.00	304.00	277.00
Mean Marshall Flow	13.00	12.50	12.30	13.67	14.30
Standard Deviation	1.00	2.08	1.15	0.58	2.13
Mean Bulk Sp. Gravity	2.304	2.320	2.354	2.300	2.337
Standard Deviation	0.017	0.021	0.022	0.055	0.017
Rice Specific Gravity **	2.465	2.468	2.441	2.417	2.397
Void Ratio **	6.53	6.02	3.58	3.97	2.52
VMA	10.52	10.88	12.32	13.65	14.82
Tests	**Kraton (4.5%) Modified Conoco II**				
Mean Marshall Stability	2206.00	3001.00	2771.00	2019.00	2160.00
Standard Deviation	840.00	270.00	267.00	69.00	122.00
Mean Marshall Flow	11.67	14.00	14.67	13.67	12.00
Standard Deviation	2.52	1.00	1.15	2.08	1.00
Mean Bulk Sp. Gravity	2.308	2.374	2.369	2.328	2.349
Standard Deviation	0.034	0.016	0.010	0.022	0.004
Rice Specific Gravity	2.475	2.431	2.423	2.420	2.406
Void Ratio	6.72	2.35	2.22	3.80	2.35
VMA	10.15	12.22	12.97	13.54	14.50
Tests	**Kraton 6% Modified Conoco II**				
Mean Marshall Stability	1264.00	1743.00	1950.00	2366.00	2436.00
Standard Deviation	264.00	126.00	156.00	149.00	97.00
Mean Marshall Flow	12.33	12.00	14.30	14.67	17.67
Standard Deviation	0.58	1.00	0.58	0.58	2.52
Mean Bulk Sp. Gravity	2.251	2.296	2.308	2.340	2.420
Standard Deviation	0.012	0.020	0.006	0.005	0.015
Rice Specific Gravity	2.474	2.449	2.421	2.393	2.361
Void Ratio	9.01	6.15	4.64	2.23	1.06
VMA	10.19	11.57	13.04	14.50	16.10

The points on the test property curve for density of Polybilt modified conoco strayed away from the curve at 6.5% at which the standard deviation was high (.055 against .024). Other curves are relatively smooth.

From Table 9 of the optimum asphalt content, it was observed that the optimum asphalt content for Kraton-6 is higher compared to all other modified and unmodified Conoco [5.82% for Conoco, 5.42% for Kraton-4.3, 6.67 for Kraton-6 and 6.2% for Polybilt modified Conoco]. The test parameter values at optimum were different for modified and unmodified Conoco. The stability values 3088 for Polybilt and 3000 for Kraton-4.3 are higher than 2643 for unmodified Conoco. The flow did not change much. The density of Kraton-6 modified Conoco remained least at 2.343. The void ratio remained around 3.25 except for Polybilt modified Conoco in which the void ratio was 4.03%. The test parameter values of the modified and unmodified Conoco remained within the Montana State specification.

Overall the results of the second set were improved to a great extent, when compared to the first set. It is also observed from the plot of the Marshall parameters in Appendix B that the point on the curve for stability, flow and density strayed away at the point of greater standard deviation.

Third Case:

The third case utilized the controlled test temperature with split aggregate. The temperature was controlled strictly. The split aggregate is heated to 325 - 335°F and the asphalt

temperature was maintained in the range of 275 - 285°F. The mix temperature just before the compaction was maintained within the limit of a specified range of temperature depending on the viscosity of unmodified asphalt. For Cenex it was 287 - 295°F and for Conoco it was 277 - 285°F. The Marshall mold specimen test data sheet was maintained to record the temperature and quantity of asphalt and aggregate for each test specimen. The test data sheet is presented in Appendix C. The operators were more careful in conducting the tests.

Table 11 shows the results of the Marshall test parameters for the Cenex. The standard deviations of the Marshall stability were all well within the 400 limit. Similarly, the standard deviation of flow values were also within the limit of .02 inch except for 5.5% Polybilt and 5%. 6%, and 7% Kraton-6 modified Cenex. In spite of the good low standard deviation results, the test property curves were not smooth. This shows that there are some other variables related to the test and preparation of the mold.

The difference of the stability value between the highest and lowest asphalt content is 600 for Cenex, 915 for Polybilt, 428 for Kraton-4.3 and 202 for Kraton-6. This shows the sensitivity of stability to the asphalt content. Similarly, the range of density values .058, .055, .053, and .055 for Cenex, Polybilt, Kraton-4.3 and Kraton-6, respectively, shows the sensitivity of the density to asphalt content. The void ratio stayed high in the case of Polybilt modified Cenex. The VMA

Table 11. Results of Marshall Test Parameters of with Splited Aggregate.

Tests	Unmodified Cenex III				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	1602.00	1931.00	1834.00	2027.00	2202.00
Standard Deviation (M.S.)	53.00	103.00	240.00	216.00	53.00
Mean Marshall Flow (M.F.)	11.67	10.33	11.67	11.33	13.00
Standard Deviation (M.F.)	1.53	0.58	1.15	1.53	1.00
Mean Bulk Sp. Gravity (B.S.G.)	2.297	2.319	2.310	2.346	2.355
Standard Deviation (B.S.G.)	0.013	0.007	0.003	0.009	0.003
Rice Specific Gravity	2.477	2.487	2.442	2.411	2.416
Void Ratio	7.28	6.74	5.40	2.69	2.49
VMA	16.62	16.26	17.03	16.18	16.31
Tests	Polybilt Modified Cenex III				
Mean Marshall Stability (M.S.)	1851.00	1491.00	1395.00	2102.00	2210.00
Standard Deviation (M.S.)	143.00	151.00	61.00	166.00	225.00
Mean Marshall Flow (M.F.)	11.67	13.33	14.00	13.33	14.33
Standard Deviation (M.F.)	0.58	2.08	1.00	1.53	1.53
Mean Bulk Sp. Gravity (B.S.G.)	2.301	2.291	2.304	2.327	2.346
Standard Deviation (B.S.G.)	0.015	0.006	0.021	0.013	0.020
Rice Specific Gravity	2.452	2.423	2.417	2.424	2.383
Void Ratio	6.15	5.46	4.67	4.03	1.56
VMA	16.47	17.27	17.24	16.86	16.63
Tests	Kraton (4.3%) Modified Cenex III				
Mean Marshall Stability (M.S.)	1992.00	2161.00	2015.00	1733.00	1784.00
Standard Deviation (M.S.)	142.00	169.00	354.00	137.00	336.00
Mean Marshall Flow (M.F.)	12.00	12.00	12.33	14.00	18.00
Standard Deviation (M.F.)	1.00	0.00	0.58	1.00	1.00
Mean Bulk Sp. Gravity (B.S.G.)	2.291	2.317	2.304	2.310	2.344
Standard Deviation (B.S.G.)	0.009	0.013	0.015	0.016	0.007
Rice Specific Gravity	2.454	2.440	2.418	2.432	2.414
Void Ratio	6.61	5.01	4.70	5.03	2.90
VMA	16.83	16.33	17.24	17.47	16.70
Tests	Kraton (6%) Modified Cenex III				
Mean Marshall Stability (M.S.)	2305.00	2176.00	2275.00	2327.00	2378.00
Standard Deviation (M.S.)	165.00	163.00	349.00	233.00	81.00
Mean Marshall Flow (M.F.)	11.33	11.33	13.67	13.00	14.33
Standard Deviation (M.F.)	2.50	0.58	2.08	1.00	2.08
Mean Bulk Sp. Gravity (B.S.G.)	2.289	2.301	2.320	2.329	2.344
Standard Deviation (B.S.G.)	0.026	0.007	0.005	0.001	0.007
Rice Specific Gravity	2.469	2.438	2.413	2.420	2.399
Void Ratio	7.28	5.62	3.83	3.75	2.32
VMA	16.91	16.91	16.67	16.79	16.70

Table 12. Optimum Asphalt Content for Asphalt Mix Based on Test Property Curves Data. Test Third Case.

Asphalt	Cenex	Kraton (4.3%) Modified Cenex	Kraton (6%) Modified Cenex	Polybilt Modified Cenex	Conoco	Kraton (4.3%) Modified Conoco	Kraton (6%) Modified Conoco	Polybilt Modified Conoco
Marshall Stability	7.00%	5.50%	7.00%	7.00%	6.00%	6.50%	6.50%	7.00%
Unit Weight	7.00%	7.00%	7.00%	7.00%	7.00%	6.50%	6.50%	7.00%
Percent Air Void	6.25%	6.73%	5.95%	6.50%	5.67%	6.10%	5.57%	6.70%
Optimum Asphalt Content	6.75%	6.41%	6.65%	6.83%	6.22%	6.37%	6.19%	6.90%
Test Parameter Values at Optimum Asphalt Content								
Marshall Stability	2193.00	2023.00	2335.00	2200.00	1846.00	2336.00	2638.00	2112.00
Marshall Flow	12.13	13.25	13.20	14.15	10.58	12.80	14.80	13.04
Bulk Specific Gravity	2.351	2.327	2.337	2.342	2.353	2.348	2.345	2.336
Percent Air Void (%)	2.83	4.20	3.10	3.58	2.89	3.14	2.10	3.79

remained above 15% in all cases.

Table 12 for optimum asphalt content shows that optimum asphalt content remained high between 6.41 to 7% for all modified and unmodified Cenex. The Marshall stability values remained within 2000 to 2335. There was not much difference in flow values between the unmodified and modified Cenex. The void ratio values are 2.83 for Cenex and 4.2% for Kraton-4.3. The parameter values at optimum asphalt content falls within the Montana State specification.

Table 13 shows that the Marshall test parameter values for modified and unmodified Conoco for the third case. The standard deviation of the Marshall stability value falls under 400 for all asphalts. Similarly, the standard deviation for flow falls under 0.02 inch for all except 6% unmodified Conoco and 7% for Kraton-6 modified Conoco. The void ratios stayed low at the higher asphalt content. VMA values were above 15%.

Table 12 for the optimum asphalt content shows that the optimum asphalt content stayed between 6 and 6.9. The stability value for unmodified Conoco is low at 1846. Relatively, the stability value improved for modified Conoco at 2112 to 2638. The density remained high for unmodified Conoco. The void ratio remained low at 2.89 and 2.10 for unmodified and Kraton-6 modified Conoco. The values are within the Montana State Highways specification except for the stability for Conoco.

<u>75 Blows Case:</u>

The Marshall specimen molds with split aggregate were made

Table 13. Results of Marshall Test Parameters with Splited Aggregate.

	Unmodified Conoco III				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	1634.00	1650.00	1872.00	1357.00	1630.00
Standard Deviation (M.S.)	249.00	110.00	156.00	292.00	172.00
Mean Marshall Flow (M.F.)	9.33	11.00	10.00	13.00	12.33
Standard Deviation (M.F.)	1.15	1.00	1.00	3.00	1.53
Mean Bulk Sp. Gravity (B.S.G.)	2.297	2.329	2.344	2.348	2.363
Standard Deviation (B.S.G.)	0.017	0.011	0.024	0.008	0.012
Rice Specific Gravity	2.477	2.451	2.424	2.407	2.408
Void Ratio	7.29	4.96	3.32	1.88	1.84
VMA	16.91	16.91	16.67	16.79	16.70
Tests	Polybilt Modified Conoco III				
Mean Marshall Stability (M.S.)	2085.00	2033.00	2065.00	2056.00	2117.00
Standard Deviation (M.S.)	81.00	208.00	145.00	93.00	80.00
Mean Marshall Flow (M.F.)	11.00	11.00	10.67	12.33	13.33
Standard Deviation (M.F.)	0.00	1.00	0.58	1.53	0.06
Mean Bulk Sp. Gravity (B.S.G.)	2.274	2.305	2.309	2.299	2.339
Standard Deviation (B.S.G.)	0.002	0.009	0.006	0.001	0.004
Rice Specific Gravity	2.469	2.454	2.424	2.416	2.374
Void Ratio	7.90	6.05	4.47	4.83	1.47
VMA	16.62	15.90	15.81	16.11	16.88
Tests	Kraton (4.3%) Modified Conoco III				
Mean Marshall Stability (M.S.)	1686.00	1810.00	1725.00	2827.00	2085.00
Standard Deviation (M.S.)	242.00	135.00	214.00	172.00	397.00
Mean Marshall Flow (M.F.)	10.67	12.00	11.33	15.00	15.33
Standard Deviation (M.F.)	0.58	1.73	1.15	1.00	1.15
Mean Bulk Sp. Gravity (B.S.G.)	2.294	2.294	2.321	2.359	2.335
Standard Deviation (B.S.G.)	0.015	0.019	0.033	0.005	0.021
Rice Specific Gravity	2.442	2.455	2.427	2.417	2.374
Void Ratio	6.07	6.53	4.33	2.40	1.62
VMA	17.45	16.77	17.06	17.86	16.88
Tests	Kraton (6%) Modified Conoco III				
Mean Marshall Stability (M.S.)	2284.00	2494.00	2327.00	2675.00	2297.00
Standard Deviation (M.S.)	237.00	359.00	326.00	344.00	315.00
Mean Marshall Flow (M.F.)	17.00	12.67	15.00	16.33	18.66
Standard Deviation (M.F.)	1.00	1.53	1.73	0.58	2.08
Mean Bulk Sp. Gravity (B.S.G.)	2.306	2.325	2.262	2.368	2.361
Standard Deviation (B.S.G.)	0.024	0.025	0.024	0.005	0.007
Rice Specific Gravity	2.471	2.447	2.408	2.409	2.397
Void Ratio	6.68	5.01	1.03	1.68	1.52
VMA	16.73	17.16	16.63	15.72	17.02

with 75 blows of compactive effort. The temperature was maintained as in the third case. Table 14 shows the result of the Marshall test parameter for 75 blows compaction for the unmodified Cenex and Conoco. The standard deviations of Marshall stability were well under 400 except for 6% Cenex. The standard deviations of Marshall flow were well under .02 inch except for 6 % Cenex and 4.5% Conoco. Similarly, the standard deviations of the density were also under .024 except for 5.5% and 6% Cenex. The standard deviation of the all test parameters for Conoco was well under the limit. This may explain why the test property curves of Conoco were smooth. As expected, the void ratio was lower at higher asphalt content. The difference between the highest and lowest stability values at different asphalt contents were 339 and 677 for Cenex and Conoco respectively. Similar differences for density were .062 and.084 for Cenex and Conoco respectively. Conoco was more sensitive to the asphalt content.

The absolute values of stability and density at 75 blows were higher than those of 50 blows for both Cenex and Conoco, while flow values remained within the same range. The optimum asphalt content for the 75 blows compacted specimen is given in Table 15. The optimum asphalt content was 6.08% for Cenex and 5.59% for Conoco. The stability was 2460 compared to 2193 for Cenex and 2385 compared to 2193 for Conoco. The Marshall flow value remained about the same (12 and 11.50 compared to 12.13 and 10.58 for Cenex and Conoco respectively). The change in density (2.384 against 2.353) for Conoco was bigger than for Cenex (2.353

Table 14. Results of Marshall Test Parameters with 75 Blows Compaction.

Tests	Unmodified Cenex with 75 Blows				
Asphalt Content	4.50%	5.00%	5.50%	6.00%	6.50%
Mean Marshall Stability (M.S.)	2328.00	2136.00	2414.00	2475.00	2317.00
Standard Deviation (M.S.)	244.00	77.00	38.00	541.00	190.00
Mean Marshall Flow (M.F.)	12.33	9.33	11.00	11.67	13.67
Standard Deviation (M.F.)	1.52	0.58	1.00	2.08	1.53
Mean Bulk Sp. Gravity (B.S.G.)	2.319	2.345	2.337	2.351	2.381
Standard Deviation (B.S.G.)	0.01	0.003	0.034	0.026	0.004
Rice Specific Gravity	2.483	2.479	2.462	2.437	2.421
Void Ratio	6.59	5.39	5.07	3.50	1.62
VMA	15.37	16.62	16.26	17.03	16.18

Tests	Unmodified Conoco with 75 Blows				
Asphalt Content	4.50%	5.00%	5.50%	6.00%	6.50%
Mean Marshall Stability (M.S.)	1721.00	2196.00	2398.00	2160.00	1893.00
Standard Deviation (M.S.)	189.00	128.00	288.00	276.00	328.00
Mean Marshall Flow (M.F.)	9.33	10.33	12.00	12.67	15.67
Standard Deviation (M.F.)	2.52	1.15	1.00	1.15	0.58
Mean Bulk Sp. Gravity (B.S.G.)	2.309	2.352	2.380	2.393	2.384
Standard Deviation (B.S.G.)	0.01	0.006	0.008	0.014	0.012
Rice Specific Gravity	2.505	2.477	2.455	2.448	2.422
Void Ratio	7.82	5.05	3.03	2.25	1.59
VMA	15.37	14.87	15.61	15.55	14.93

Table 15. Optimum Asphalt Content for Asphalt Mix Based on Test Property Curv Data. For 75 Blows

Asphalt	Cenex	Kraton (6%) Modified Cenex	Polybilt Modified Cenex	Conoco	Kraton (6%) Modified Conoco	Polybilt Modified Conoco
Marshall Stability	6.00%			5.50%		
Unit Weight	6.50%			6.00%		
Percent Air Void	5.75%			5.27%		
Optimum Asphalt Conten	6.08%			5.59%		
Test Parameter Values at Optimum Asphalt Content						
Marshall Stability	2460.00			2385.00		
Marshall Flow	12.00			11.50		
Bulk Specific Gravity	2.353			2.384		
Percent Air Void (%)	3.18			3.10		

against 2.351). As the optimum asphalt content was reduced from 6.75 for 50 blows to 6.08 for 75 blows in the case of Cenex, the void ratio was increased to the more acceptable range of 3.18 from 2.83. Similarly, asphalt content was reduced from 6.22 to 5.59 for Conoco by increasing the compactive effort; the void ratio was increased to 3.10 from 2.89. These values are in a more acceptable range.

Controlled Aggregate:

This set of tests was carried out with controlled aggregate as discussed in the aggregate discussion. It was observed that minus #200 sieve size particle amounts were consistently low in all test specimens. There were only 2.5% of minus #200 instead of 6% (4.5 to 7.5% range). The low in fines, as a variable in the aggregate sample, may have caused the cause of higher errors. Because of the low in fines smooth test property curves did not result. A high void ratio and high asphalt content in both modified and unmodified asphalt were evident. To eliminate this effect each set of aggregate was meticulously made utilizing the median value of the specification band of the aggregate. The whole process was randomized and the sampling scheme was prepared to minimize the effect of ignored variables (operator, equipment and small differences of temperatures). Only three asphalt variables were considered for this set of randomized testing. They were unmodified Cenex, Kraton-6, and Polybilt modified Cenex. Another set of tests for Conoco were conducted in the same way.

The Marshall mold specimens were prepared in the randomized order including the replication of three molds at each asphalt content. The Marshall parameter tests were also conducted in the same random order. The results obtained are shown in Table 16. The improvement achieved by increasing compactive effort was greater than that achieved by modification as shown in Figure 2, 3, 4, and 5. The relative differences of test data at optimum asphalt content between the unmodified and modified Cenex compared to split aggregate and 75 blows data are shown in Figures 6, 7, 8, and 9.

The test property curves for the randomized controlled aggregate were relatively smooth as shown in Appendix B. There are no data points that deviate appreciably from the curves, which display definite maximum curve form.

From Table 16, it is noticed that the standard deviations are below 400 except for Polybilt and Kraton-6 modified Cenex (409 at 5.5% and 445 at 5% asphalt content respectively). The standard deviations of Marshall flow are all below .02 inch except for Polybilt (2.51 at 5%, 3 at 6%, 2.08 at 6.5%, and 2.65 at 7%) and Kraton-6 (2.31 at 6.5%) modified Cenex. The standard deviation for the bulk specific gravity (density) is all under .024 except for Kraton-6 (.032 at 5.5% asphalt) modified Cenex.

The difference between maximum and minimum stability values for the range of asphalt content is 464, 479, and 635 for unmodified Cenex, Polybilt and Kraton-6 modified Cenex, respectively. Similar differences for flow are 4.00, 2.00, and

Table 16. Results of Marshall Test Parameters with Controlled Aggregate.

Tests	Unmodified Cenex Controlled Aggregate				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	2225.00	2330.00	2426.00	2037.00	1958.00
Standard Deviation (M.S.)	295.00	399.00	40.00	299.00	254.00
Mean Marshall Flow (M.F.)	11.33	11.67	12.67	15.33	15.33
Standard Deviation (M.F.)	0.58	0.58	0.58	0.58	1.53
Mean Bulk Sp. Gravity (B.S.G.)	2.359	2.379	2.395	2.369	2.381
Standard Deviation (B.S.G.)	0.010	0.032	0.011	0.027	0.002
Rice Specific Gravity	2.468	2.460	2.452	2.421	2.414
Standard Deviation (R.S.G.)	0.008	0.002	0.008	0.009	0.011
Void Ratio Percent (V.R.)	4.42	3.28	2.33	2.16	1.36
Standard Deviation (V.R.)	0.116	1.320	0.168	1.210	0.481
VMA	14.37	14.09	13.97	15.36	15.39

Tests	Polybilt Modified Cenex Controlled Aggregate				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	2261.00	2425.00	2485.00	2438.00	2006.00
Standard Deviation (M.S.)	381.00	409.00	300.00	165.00	161.00
Mean Marshall Flow (M.F.)	15.33	13.00	14.00	17.30	15.00
Standard Deviation (M.F.)	2.51	1.00	3.00	2.08	2.65
Mean Bulk Sp. Gravity (B.S.G.)	2.358	2.377	2.392	2.383	2.371
Standard Deviation (B.S.G.)	0.010	0.007	0.009	0.013	0.006
Rice Specific Gravity	2.470	2.470	2.435	2.426	2.414
Standard Deviation (R.S.G.)	0.012	0.023	0.008	0.009	0.005
Void Ratio Percent (V.R.)	4.53	3.75	1.77	1.77	1.78
Standard Deviation (V.R.)	0.410	0.679	0.325	0.061	0.045
VMA	14.40	14.17	14.08	14.86	15.74

Tests	Kraton (6%) Modified Cenex Controlled Aggregate				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	2306.00	2382.00	2286.00	2279.00	1747.00
Standard Deviation (M.S.)	445.00	329.00	164.00	243.00	177.00
Mean Marshall Flow (M.F.)	11.67	13.33	15.00	17.33	20.00
Standard Deviation (M.F.)	0.58	1.15	1.00	2.31	0.00
Mean Bulk Sp. Gravity (B.S.G.)	2.345	2.359	2.364	2.371	2.359
Standard Deviation (B.S.G.)	0.017	0.032	0.010	0.008	0.008
Rice Specific Gravity	2.462	2.465	2.439	2.413	2.399
Standard Deviation (R.S.G.)	0.006	0.005	0.023	0.013	0.001
Void Ratio Percent (V.R.)	4.73	4.30	2.93	1.77	1.68
Standard Deviation (V.R.)	0.669	1.129	0.590	0.484	0.246
VMA	14.40	14.17	14.08	14.86	15.74

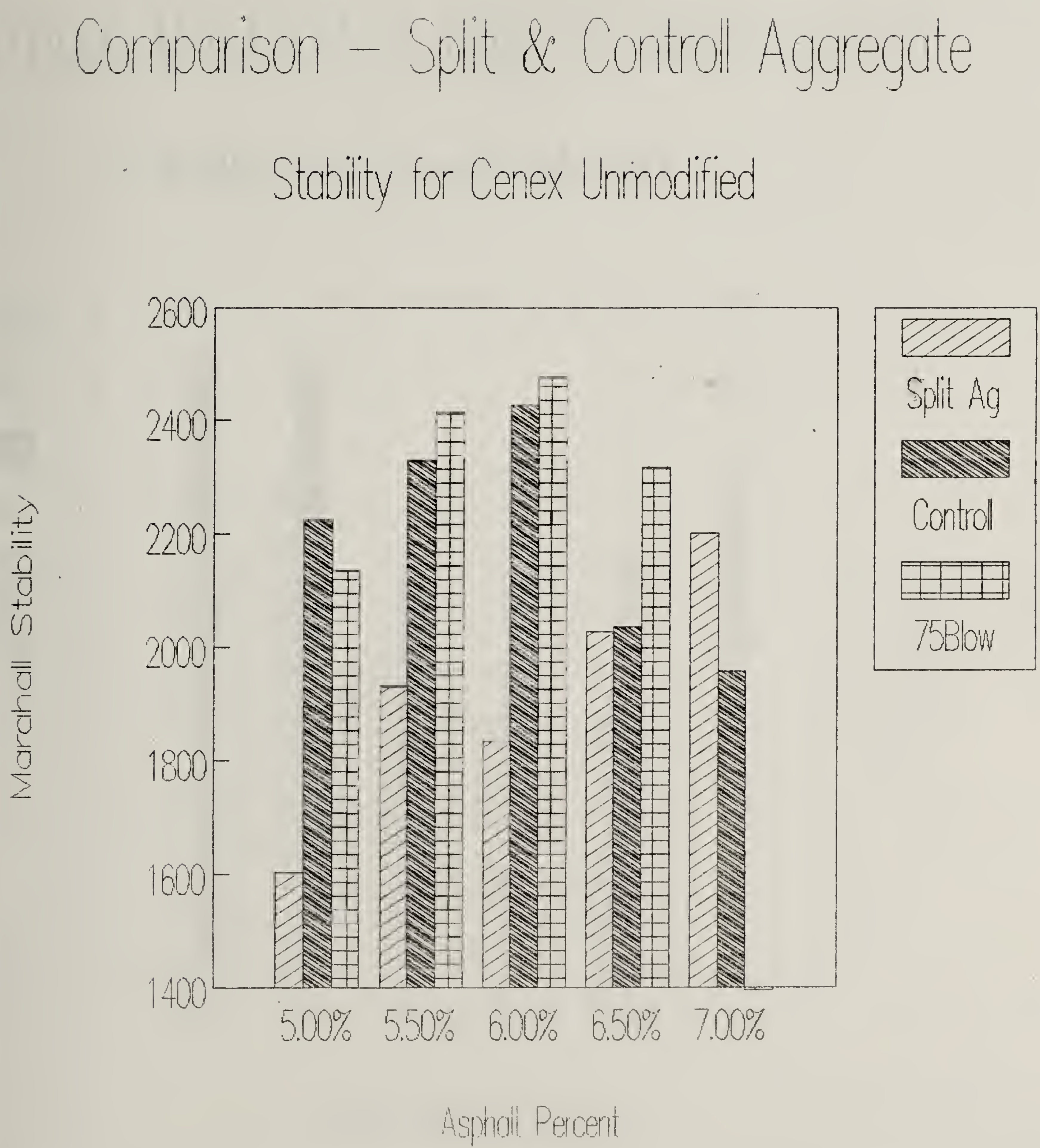

Figure 2. Comparison of Stability of Cenex with Split, Controlled Aggregate and 75 Blows compaction

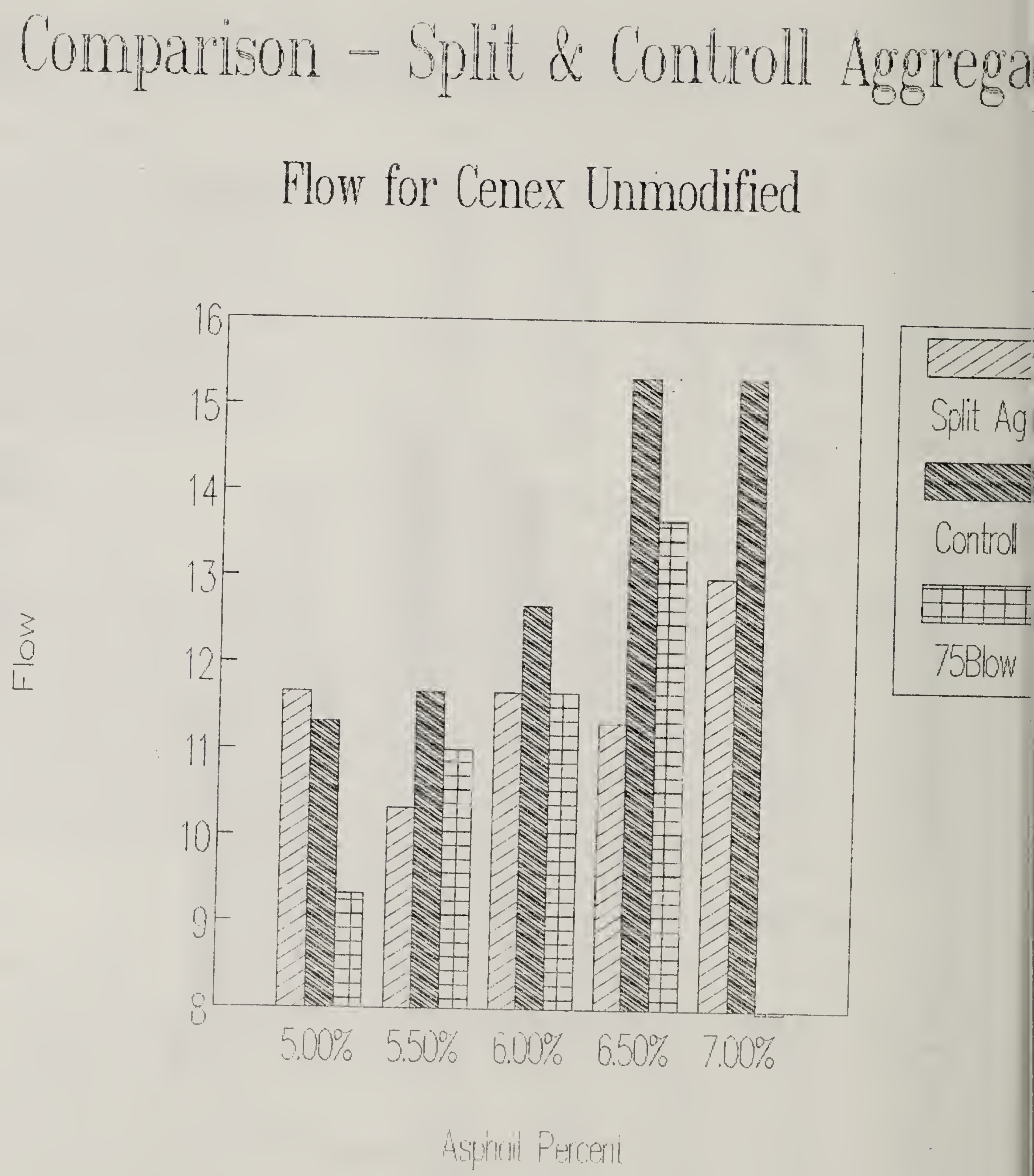

Figure 3. Comparison of Flow of Cenex with Split, Controlled Aggregate and 75 Blows compaction

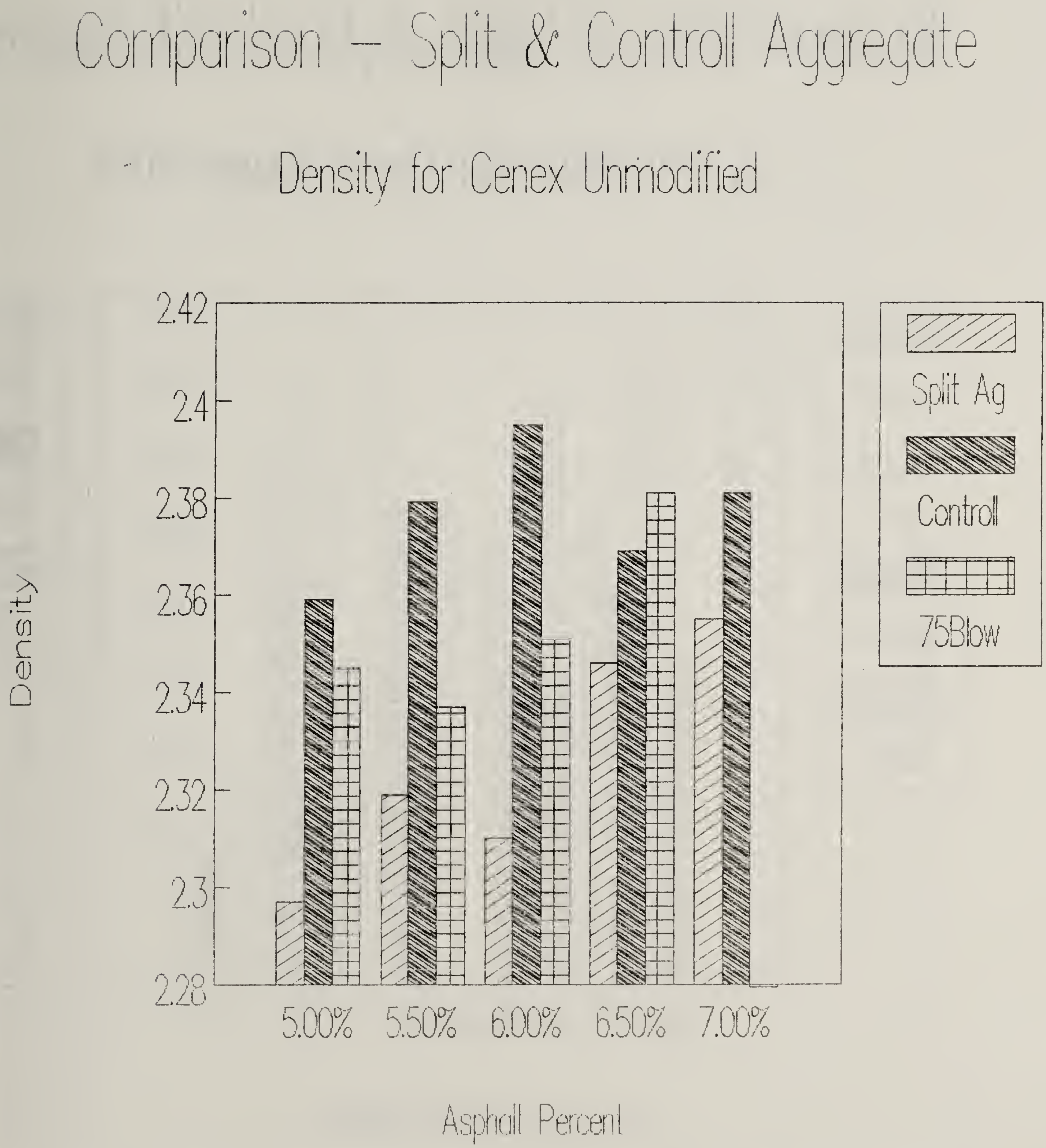

Figure 4. Comparison of Density of Cenex with Split, Controlled Aggregate and 75 Blows compaction

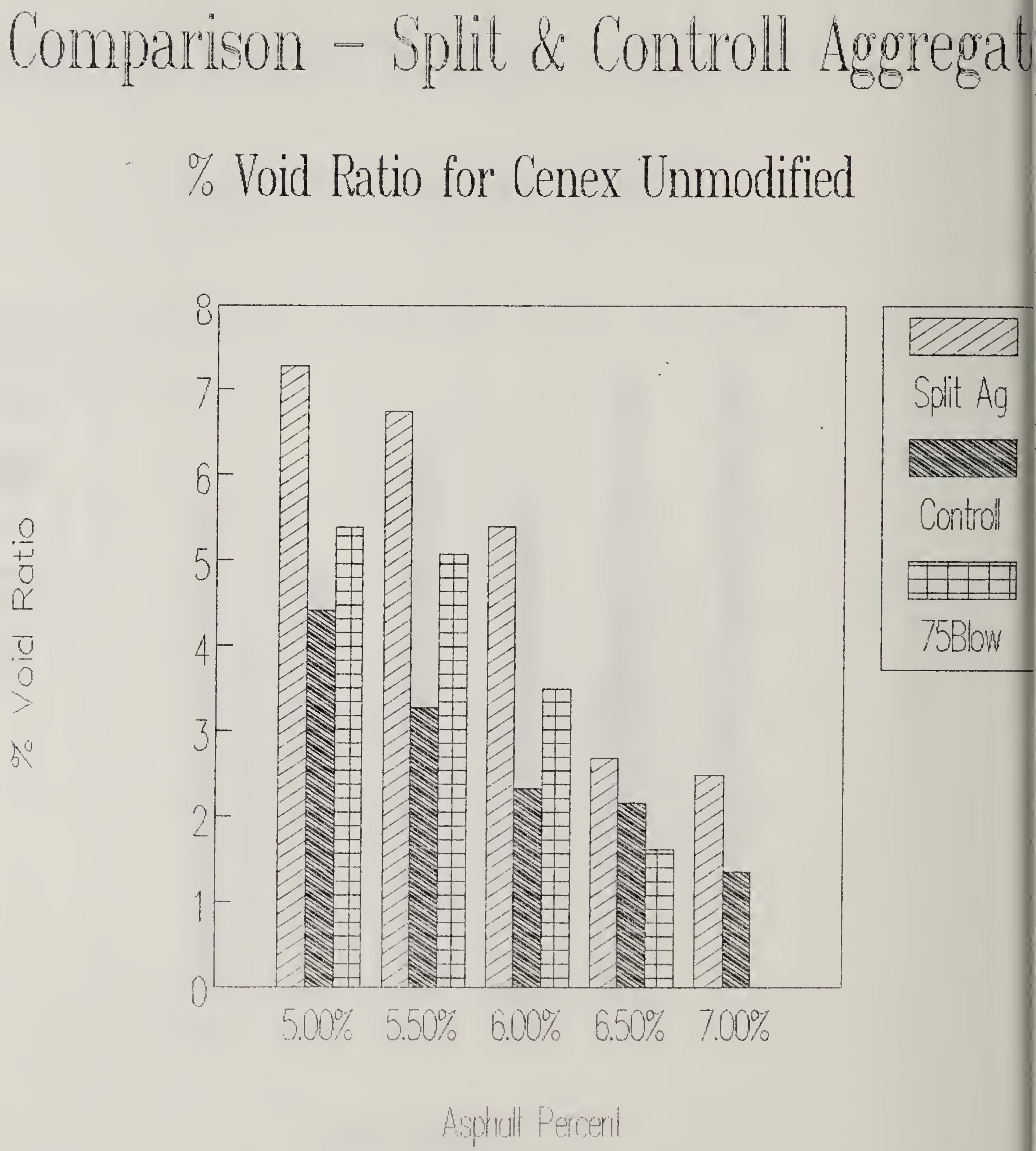

Figure 5. Comparison of Void Ratio of Cenex with Split, Controlled Aggregate and 75 Blows compaction

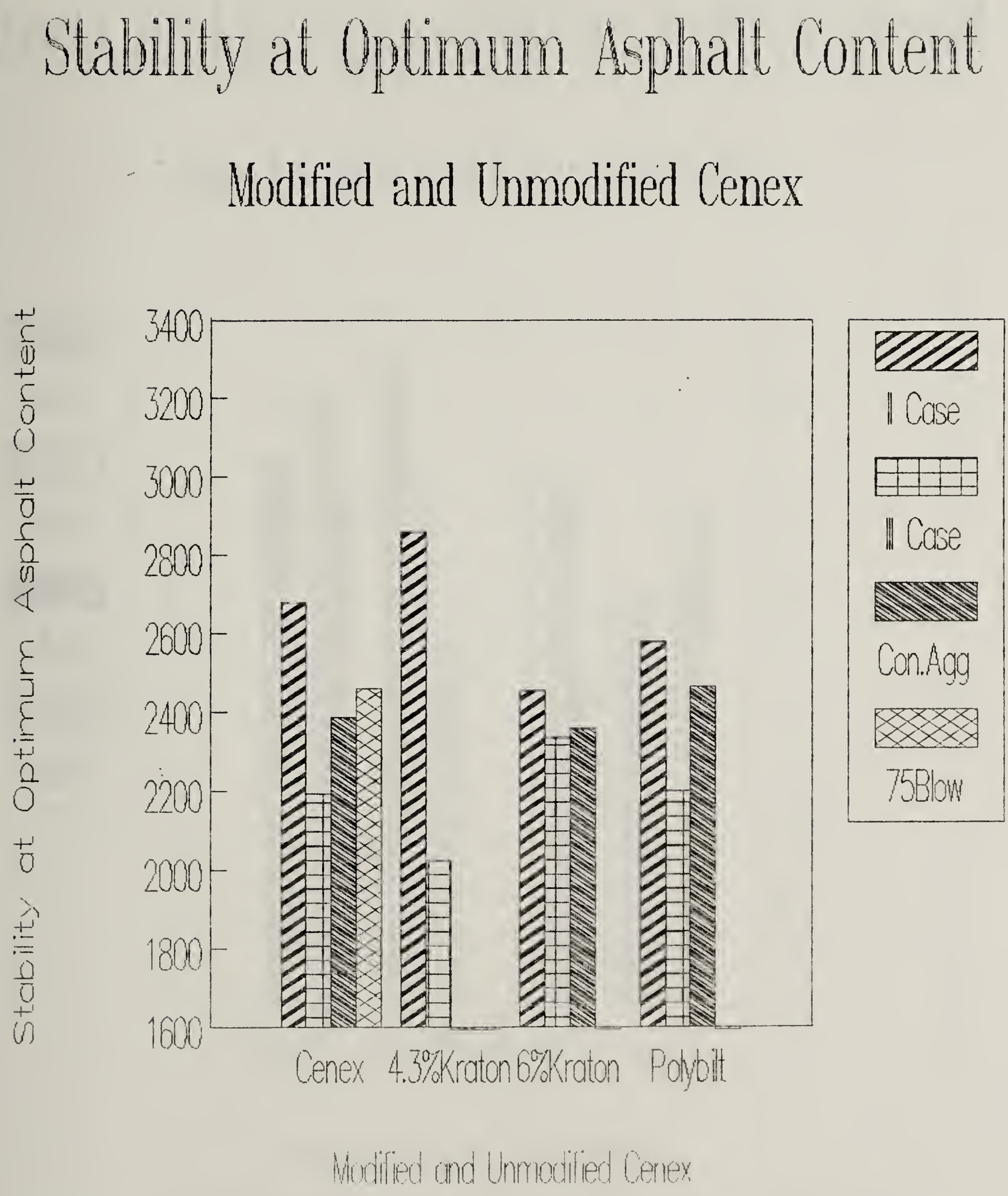

Figure 6. Relative Difference of Stability Between Split Aggregate and 75 Blows

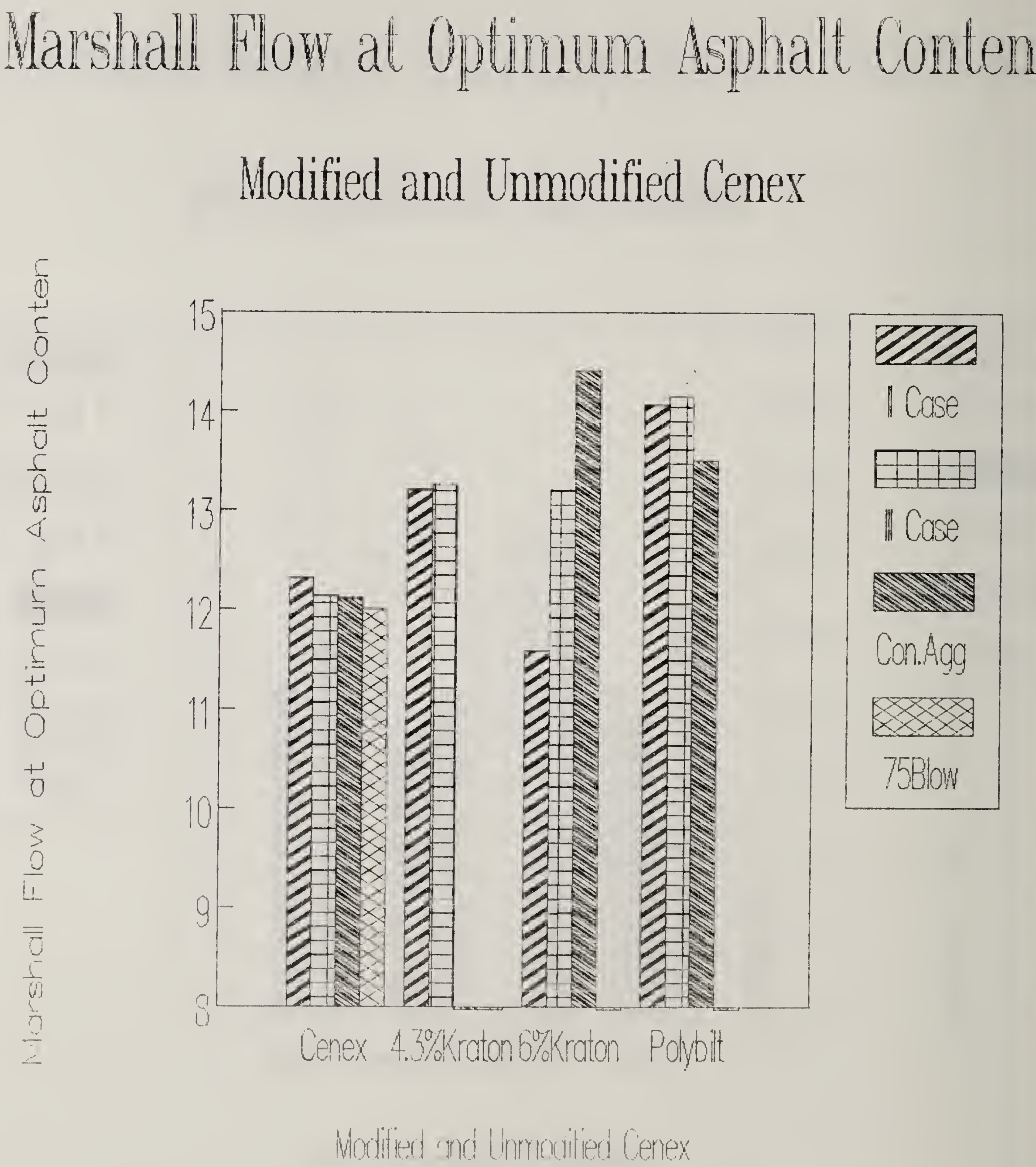

Figure 7. Relative Difference of Flow Between Split Aggregate and 75 Blows

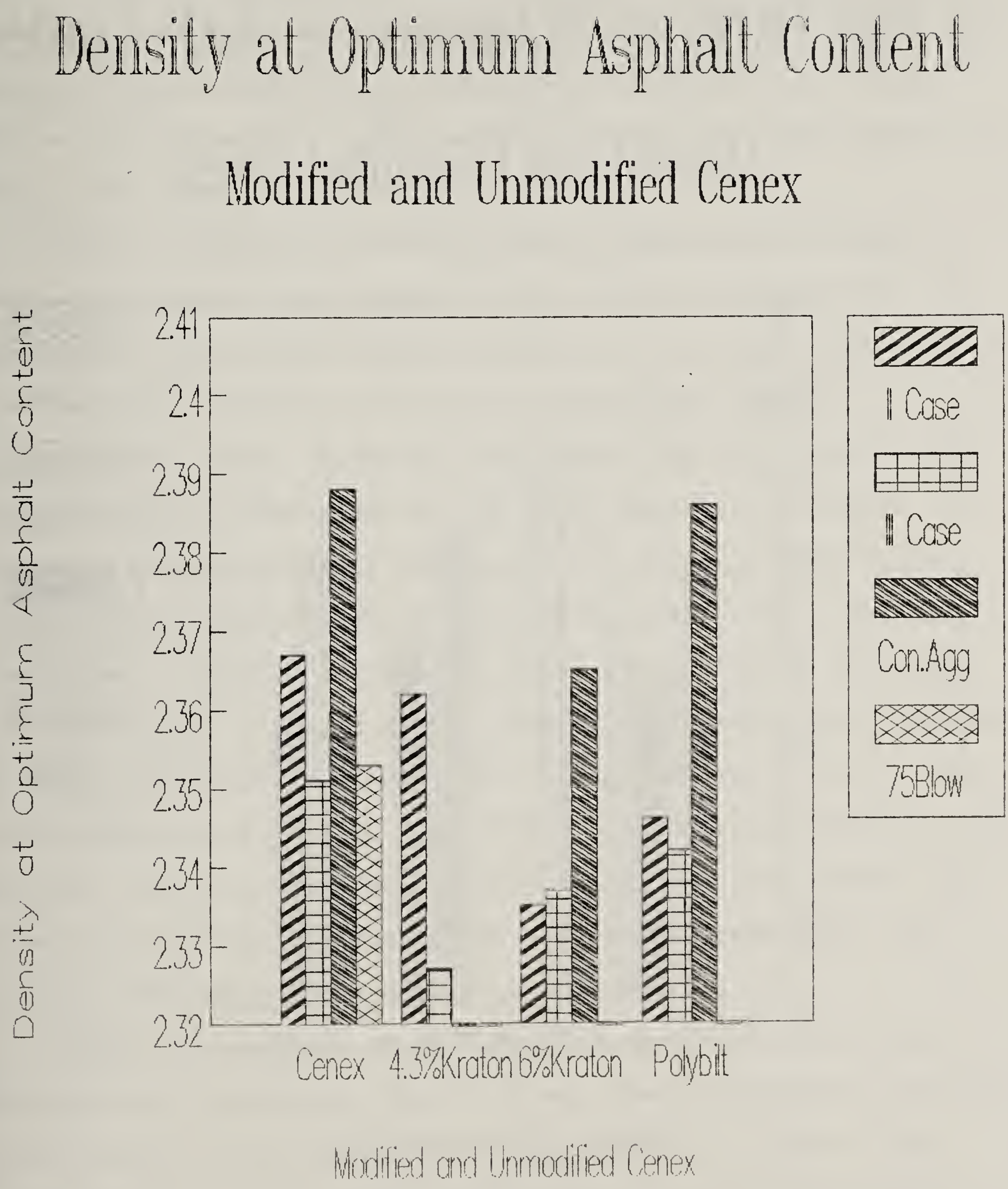

Figure 8. Relative Difference of Density Between Split Aggregate and 75 Blows

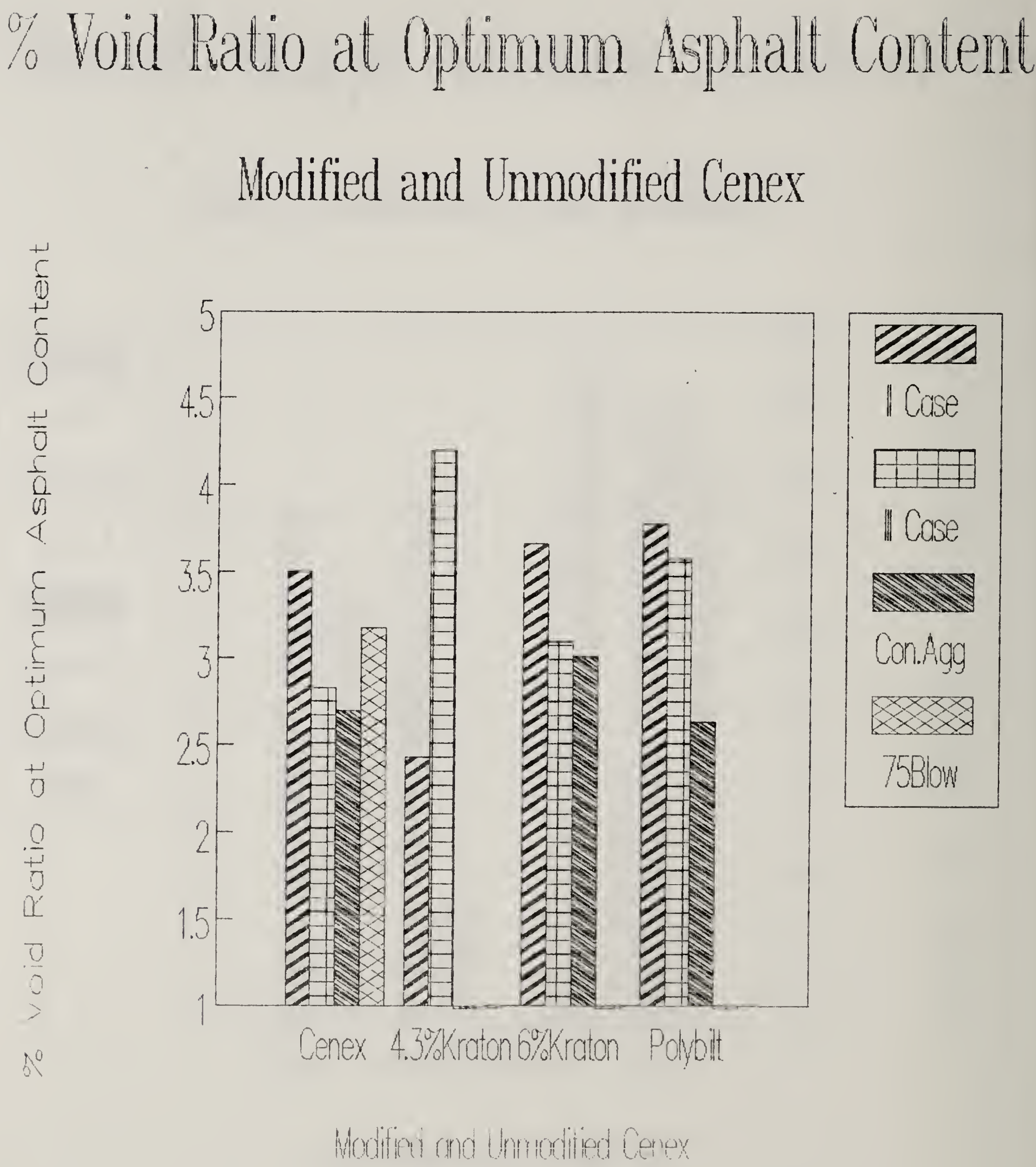

Figure 9. Relative Difference of Void Ratio Between Split Aggregate and 75 Blows

8.33 for unmodified, Polybilt, and Kraton-6 modified Cenex. Differences of density at different asphalt contents are .026, .034 and .026 for unmodified cenex, Polybilt and Kraton-6 modified Cenex respectively. Specified percentage void ratio values are achieved at lower asphalt content. The VMA values are low in the range of 14 to 15%.

Table 17 shows the optimum asphalt contents for asphalt mixes based on the test property curve data for controlled aggregate. The optimum asphalt content is 5.72,5.85, and 5.73 for the Kraton-6, Polybilt modified and unmodified asphalt, respectively. These values are the lowest asphalt contents particularly in comparison to the split aggregate results. Marshall stability values between the unmodified and modified Cenex are not much different (2386, 2357, 2465). The densities are higher, compared to those of split aggregate and 75 blows. The flow values are high in the case of modified asphalt compared to those of unmodified Cenex (14.4, 13.5 compared to 12.1). The void ratios are 2.7, 2.6, and 3.01% for unmodified, Polybilt and Kraton-6 modified Cenex respectively. Although void ratios for Cenex and Polybilt modified Cenex are on the lower side, the results meet the Montana Highway specification.

Table 18 shows the means and standard deviations of the modified and unmodified Conoco. It was observed that the standard of deviation of the Marshall stability and unit weight values remained below 400 and .024 respectively. However, the standard deviation of the Marshall flow values were above .02 inch for

Table 17. Optimum Asphalt Content for Asphalt Mix Based on Test Property Curves D
For Controlled Aggregate.

Asphalt	Cenex	Kraton (6%) Modified Cenex	Polybilt Modified Cenex	Conoco	Kraton (6%) Modified Conoco	Polybil Modifie Conoco
Marshall Stability	6.00%	5.50%	6.00%	5.50%	6.00%	5.5
Unit Weight	6.00%	6.50%	6.00%	5.00%	5.50%	5.5
Percent Air Void	5.15%	5.56%	5.18%	6.00%	6.00%	6.5
Optimum Asphalt Conten	5.72%	5.85%	5.73%	5.50%	5.83%	5.8
Test Parameter Values at Optimum Asphalt Content						
Marshall Stability	2386.00	2357.00	2465.00	2340.00	2632.00	2636.0
Marshall Flow	12.10	14.40	13.50	11.54	15.25	15.1
Bulk Specific Gravity	2.388	2.365	2.386	2.387	2.379	2.38
Percent Air Void Ratio	2.70	3.01	2.64	3.00	2.74	2.7

Table 18. Results of Marshall Test Parameters with Controlled Aggregate.

Tests	Unmodified Conoco Controlled Aggregate				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	2314.00	2340.00	2123.00	2102.00	2074.00
Standard Deviation (M.S.)	0.00	227.00	84.00	155.00	157.00
Mean Marshall Flow (M.F.)	11.33	11.33	13.67	14.33	19.00
Standard Deviation (M.F.)	0.58	0.58	0.58	1.15	2.00
Mean Bulk Sp. Gravity (B.S.G.)	2.383	2.387	2.398	2.390	2.387
Standard Deviation (B.S.G.)	0.006	0.013	0.006	0.006	0.005
Mean Rice Specific Gravity (R.S.G.)	2.481	2.462	2.443	2.416	2.398
Standard Deviation (R.S.G.)	0.024	0.012	0.010	0.015	0.019
Void Ratio Percent (V.R.)	3.97	3.03	1.83	1.07	0.99
Standard Deviation (V.R.)	1.149	0.512	0.455	0.391	0.120
VMA	14.37	14.09	13.97	15.36	15.39

Tests	Polybilt Modified Conoco Controlled Aggregate				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	2496.00	2739.00	2565.00	2357.00	2087.00
Standard Deviation (M.S.)	260.00	54.00	91.00	159.00	143.00
Mean Marshall Flow (M.F.)	11.33	14.67	16.00	16.33	18.33
Standard Deviation (M.F.)	0.58	2.52	1.73	0.58	1.53
Mean Bulk Sp. Gravity (B.S.G.)	2.363	2.385	2.387	2.390	2.382
Standard Deviation (B.S.G.)	0.006	0.005	0.015	0.006	0.004
Mean Rice Specific Gravity (R.S.G.)	2.481	2.423	2.433	2.418	2.408
Standard Deviation (R.S.G.)	0.006	0.116	0.006	0.004	0.003
Void Ratio Percent (V.R.)	4.76	3.94	1.88	1.17	1.08
Standard Deviation (V.R.)	0.295	1.010	0.496	0.162	0.289
VMA	14.40	14.17	14.08	14.86	15.74

Tests	Kraton (6%) Modified Conoco Controlled Aggregate				
Asphalt Content	5.00%	5.50%	6.00%	6.50%	7.00%
Mean Marshall Stability (M.S.)	2342.00	2253.00	2678.00	2100.00	2258.00
Standard Deviation (M.S.)	202.00	173.00	188.00	222.00	162.00
Mean Marshall Flow (M.F.)	12.67	14.33	16.33	18.00	25.00
Standard Deviation (M.F.)	1.15	1.53	2.52	2.64	6.24
Mean Bulk Sp. Gravity (B.S.G.)	2.349	2.370	2.384	2.377	2.377
Standard Deviation (B.S.G.)	0.005	0.014	0.010	0.003	0.006
Mean Rice Specific Gravity (R.S.G.)	2.458	2.468	2.427	2.390	2.397
Standard Deviation (R.S.G.)	0.014	0.015	0.021	0.015	0.010
Void Ratio Percent (V.R.)	4.43	3.98	1.76	0.67	0.83
Standard Deviation (V.R.)	0.725	0.064	0.470	0.480	0.255
VMA	14.87	14.82	15.09	15.29	16.17

5.5% Polybilt modified Conoco and for 6%, 6.5% and 7% Kraton-6 modified Conoco. The range of highest and lowest stability values of five different asphalt content were 266, 652 and 578 for unmodified Conoco, Polybilt and Kraton modified Conoco respectively. This indicated that unmodified Conoco was not as sensitive to asphalt content as modified Conoco. The data of Kraton modified Conoco fluctuated some what even though there was a definite peak value. Whereas unmodified and Polybilt modified Conoco had a smooth curve with definite peak value as shown in the Appendix B.

From Table 17, it was observed that the optimum asphalt content were 5.5, 5.83 and 5.83 for unmodified Conoco, Polybilt and Kraton modified Conoco respectively. It indicated that the optimum asphalt content for modified asphalt were higher to unmodified asphalt. The Marshall stability and flow values were increased by about same degree (2632 and 2636 versus 2340 and 15.25 and 15.15 versus 11.54) due to modification of Conoco. The void ratios were decreased to almost same degree (2.74 and 2.71 versus 3) because of modification of Conoco. However, unit weight of Kraton modified asphalt decreased while that of polybilt modified Conoco remained same as unmodified Conoco. Low void ratio and high Marshall stability for modified Conoco could indicate that modification could result in better compaction with 50 blows.

Figures 10, 11, 12, and 13 show the comparison of split, controlled aggregate with 50 blows and split aggregate with 75

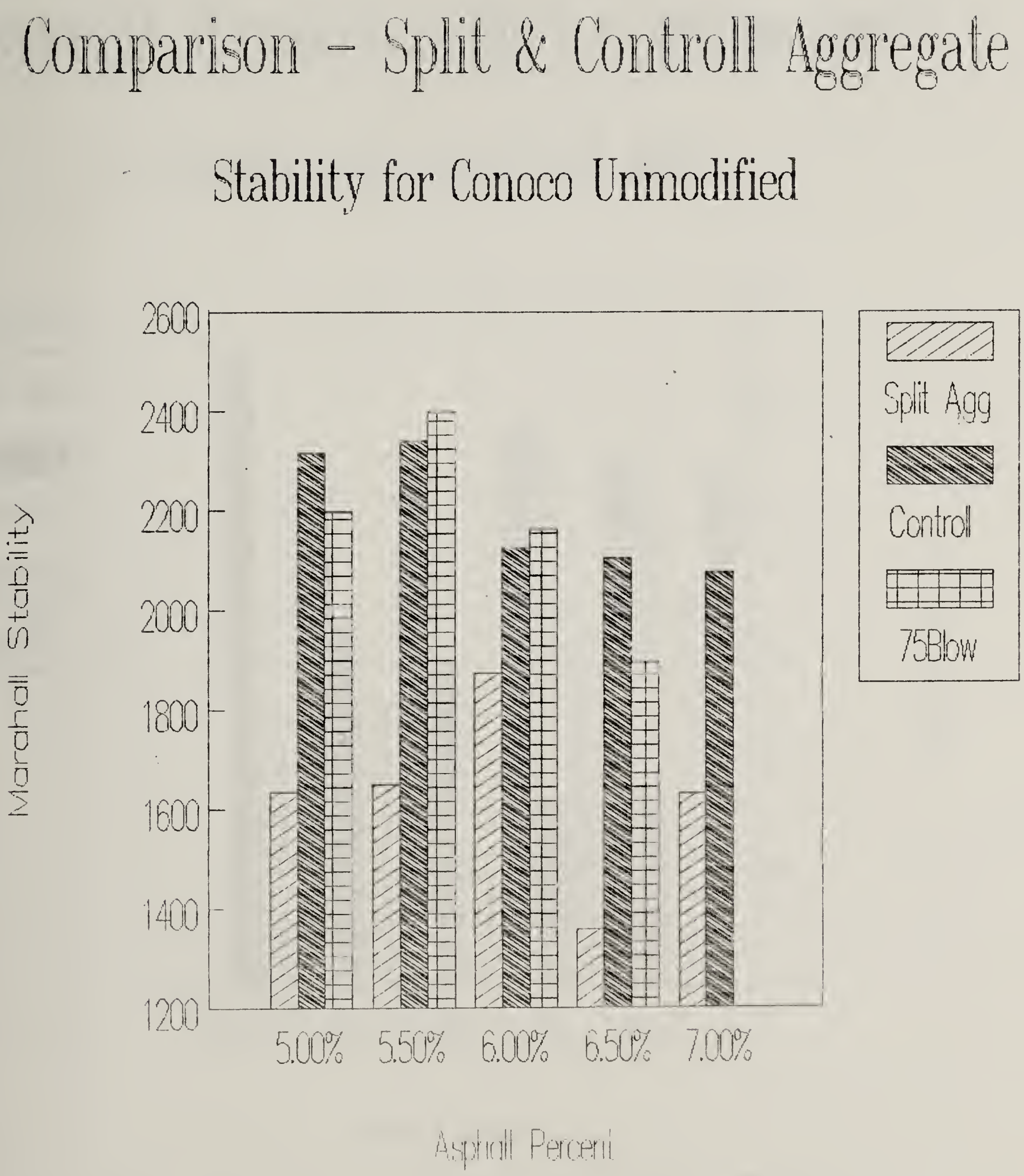

Figure 10. Comparison of Stability of Conoco with Split, Controlled Aggregate and 75 Blows compaction

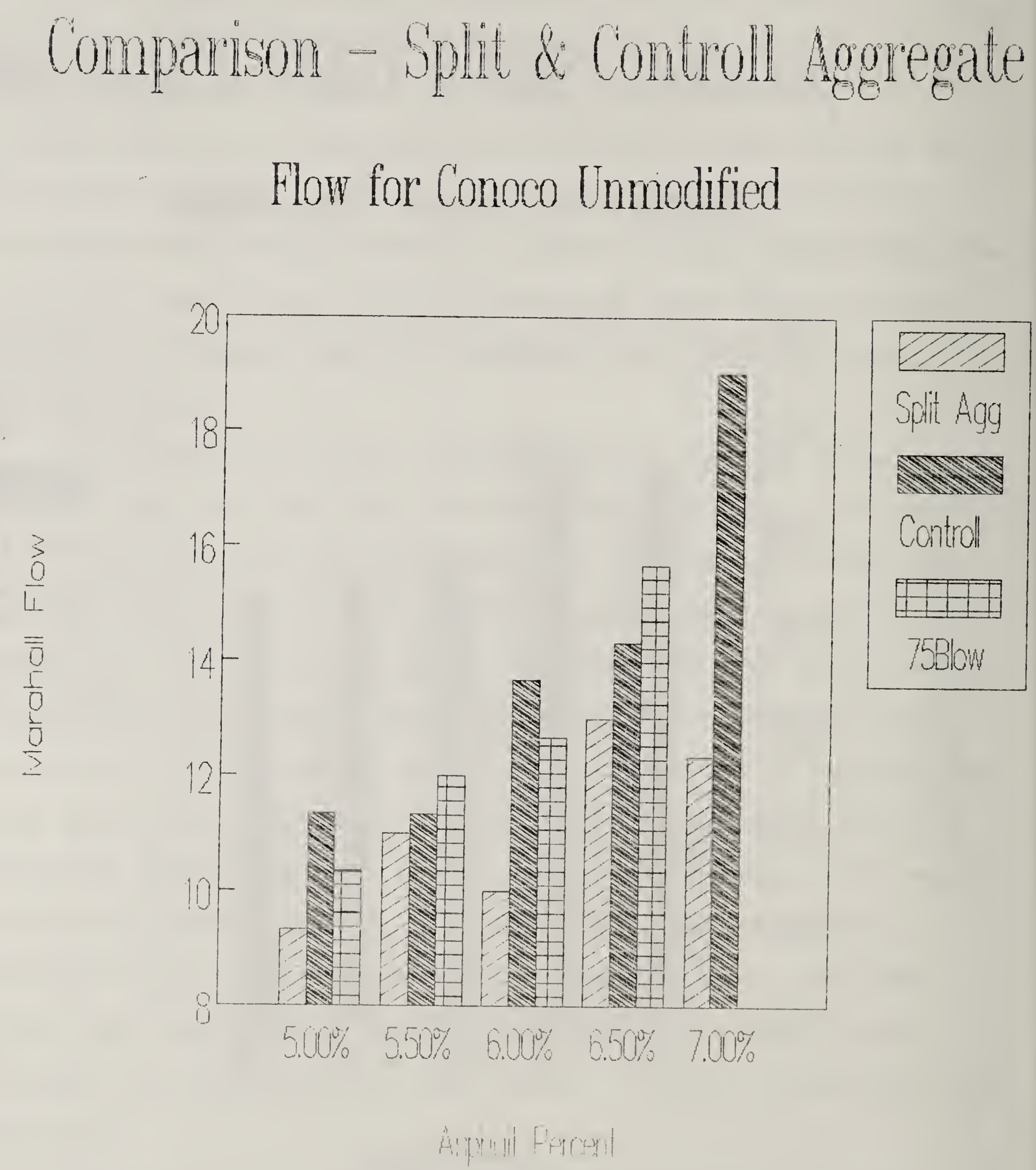

Figure 11. Comparison of Flow of Conoco with Split, Controlled Aggregate and 75 Blows compaction

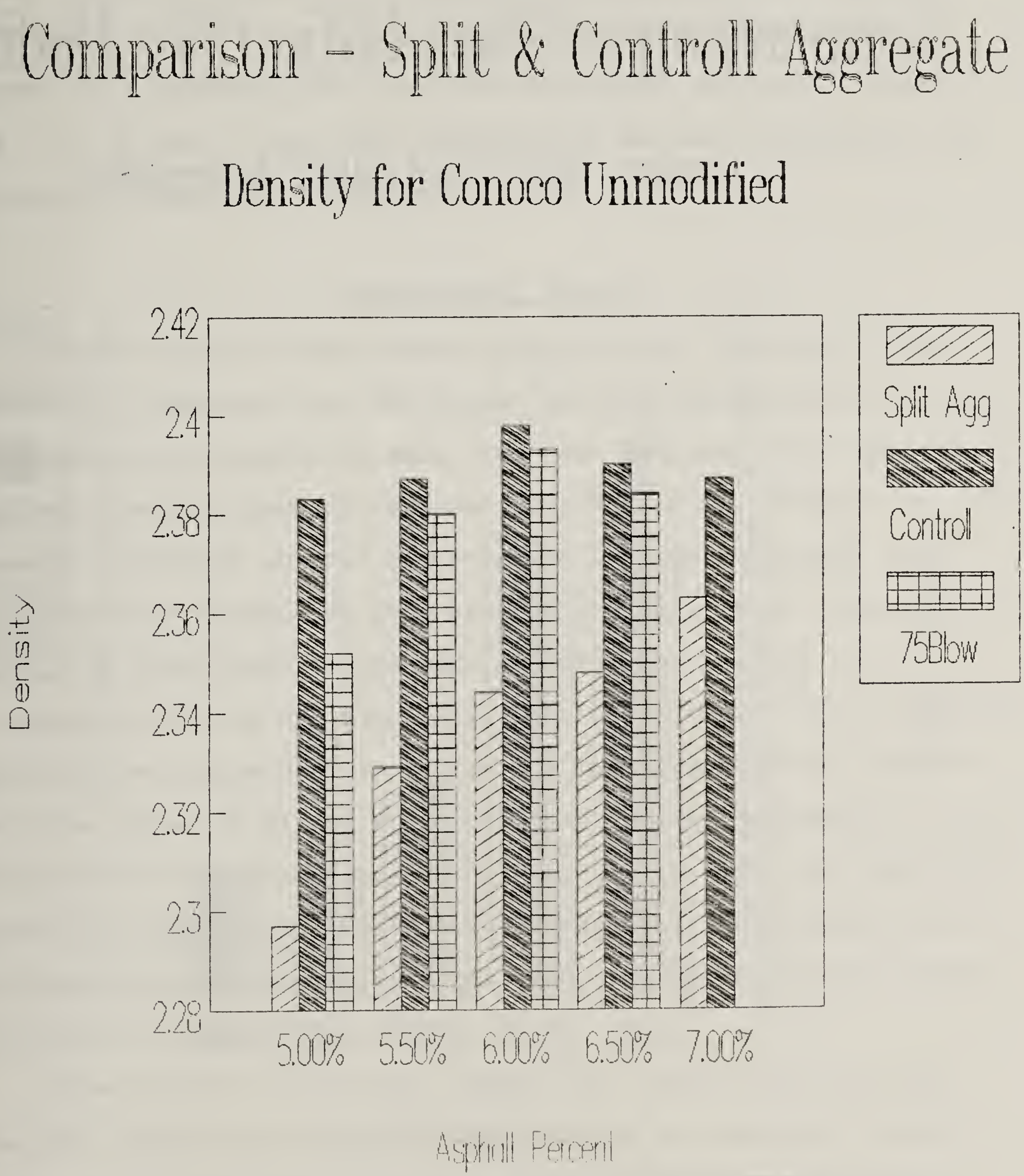

Figure 12. Comparison of Density of Conoco with Split, Controlled Aggregate and 75 Blows compaction

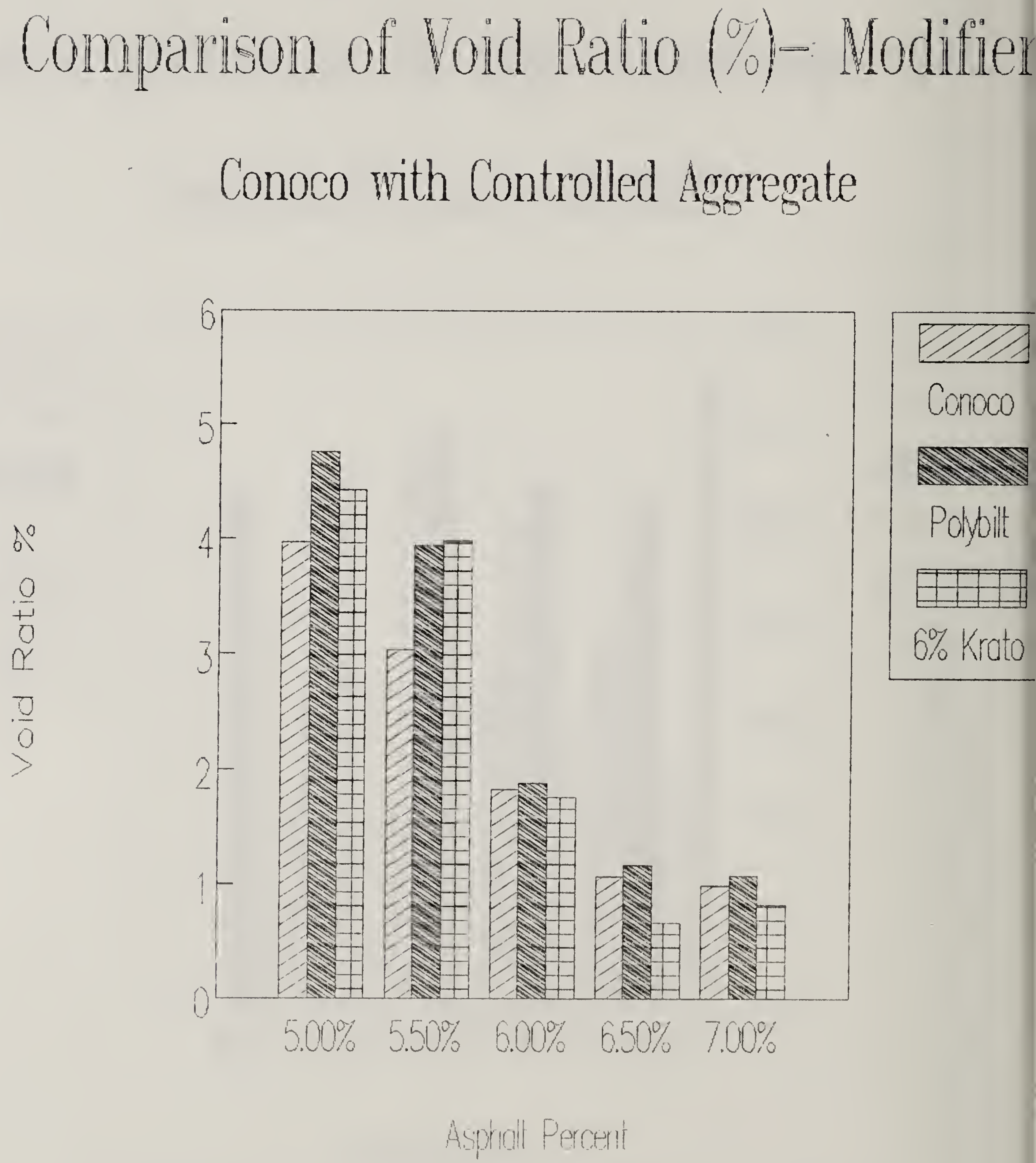

Figure 13. Comparison of Void Ratio of Conoco with Split, Controlled Aggregate and 75 Blows compaction

blows compaction for the Marshall parameters, stability, flow, unit weight and void ratio respectively. It was observed that parameter values at all asphalt content were improved with controlled aggregate and 75 blows compaction. Similarly, Figure 14, 15, 16 and 17 show the comparison of Marshall parameters for unmodified and modified Conoco.

EXPERIMENTAL DESIGN

Differences in test results between split aggregate, and controlled aggregate and the number of blows between the modified and unmodified asphalt in each case were noticed. It is important to know whether these differences were caused by different control variables or from the error of ignored variables, and whether these difference were significant at a given confidence level. An experiment begins with defining the problem. The response variables are stability, density and void ratio. The qualitative independent variables are the percentage of asphalt and the number of blows; while the qualitative independent variables are modified and unmodified asphalt, and split and controlled aggregates. Different combinations of variables were designed and the results were analyzed. The SAS computer program was used to analyze the results.

The analysis of variance (ANOVA) was carried out by using the SAS computer package. It was necessary to determine whether there was statistical difference between the two independent variables and dependent variables. This was determined by using

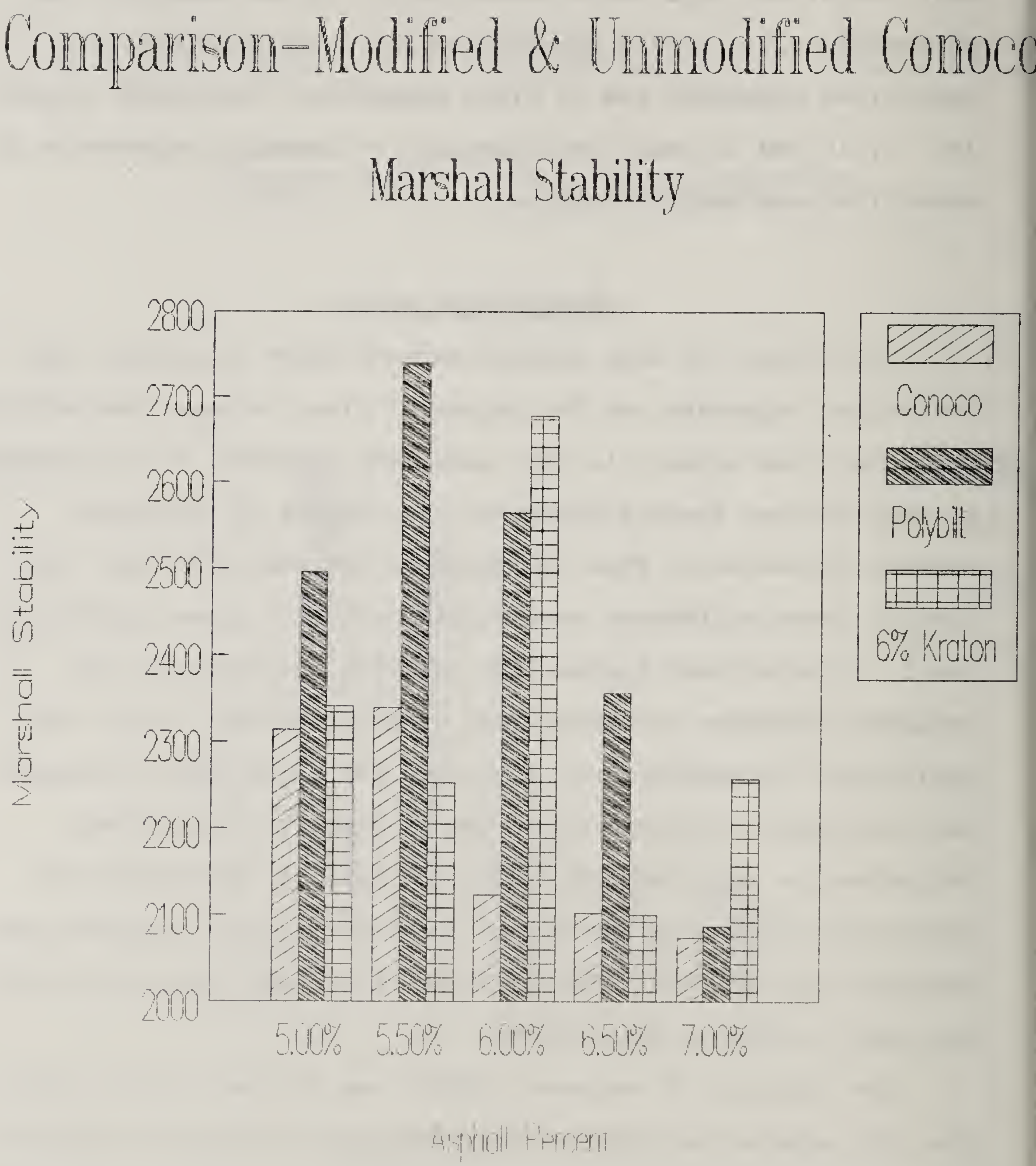

Figure 14. Comparison of Stability with Modified and Unmodified Conoco

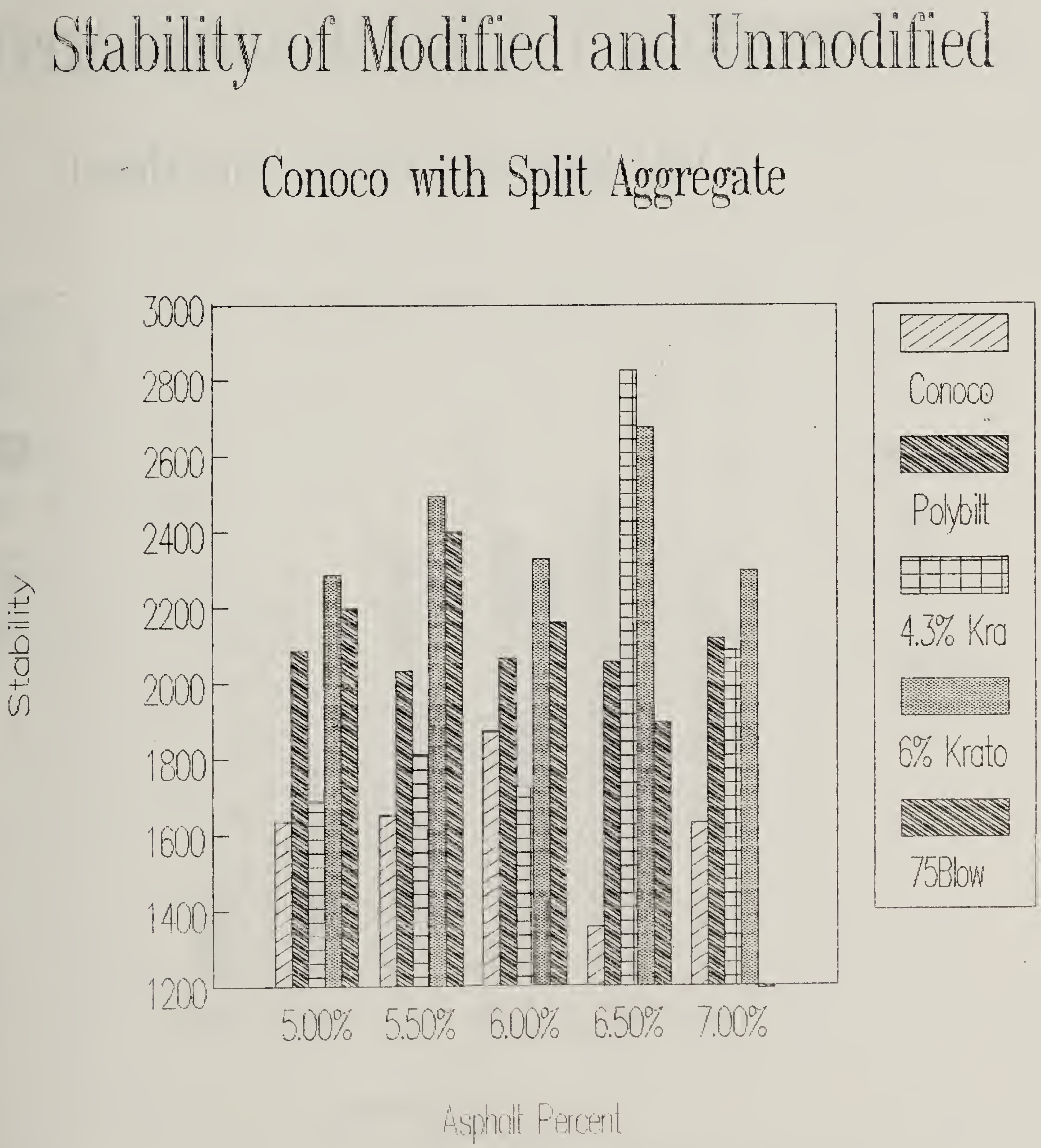

Figure 15. Comparison of Stability with Modified and Unmodified Conoco

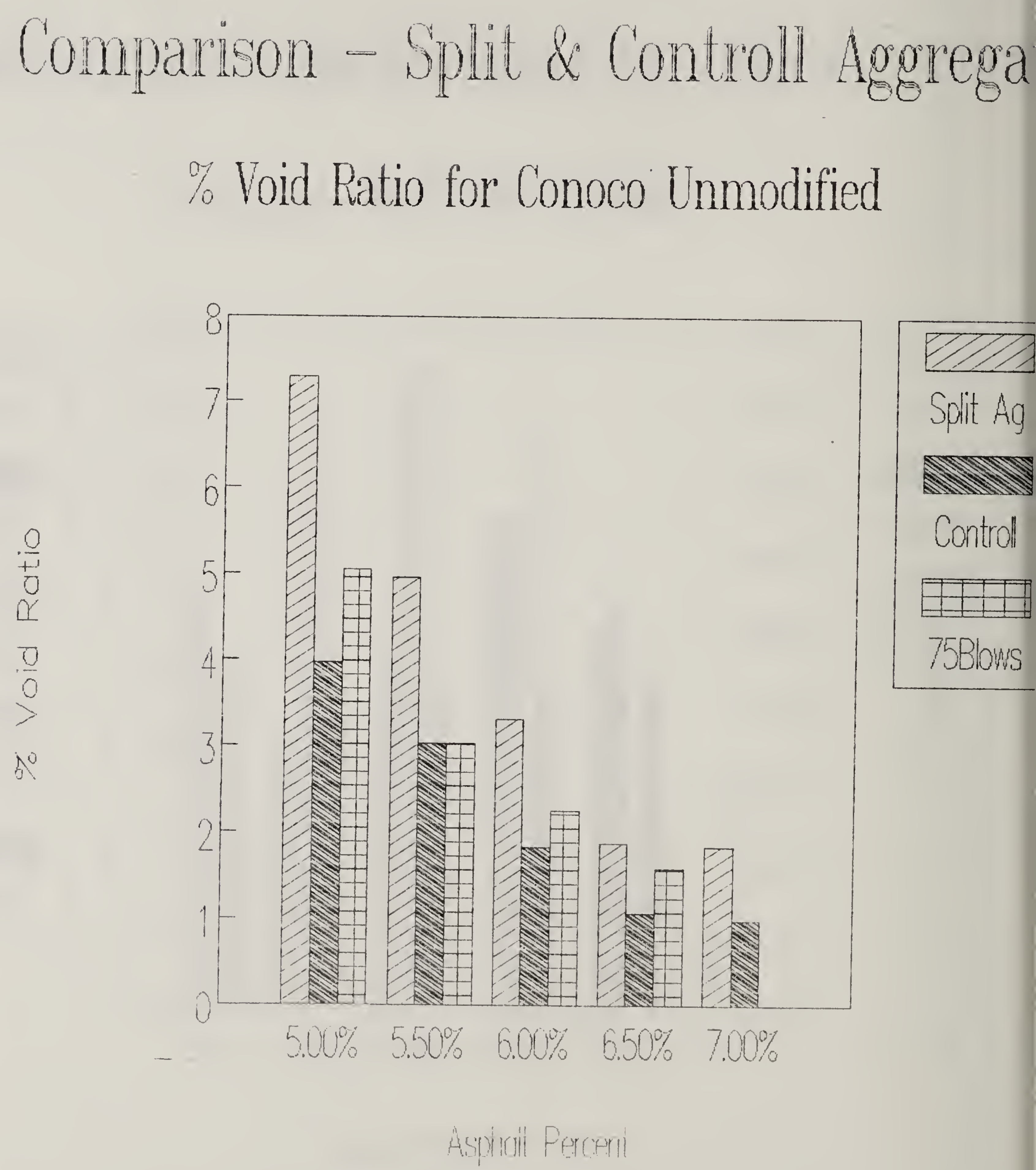

Figure 18. Comparison of Void Ratio with Modified and Unmodified Conoco

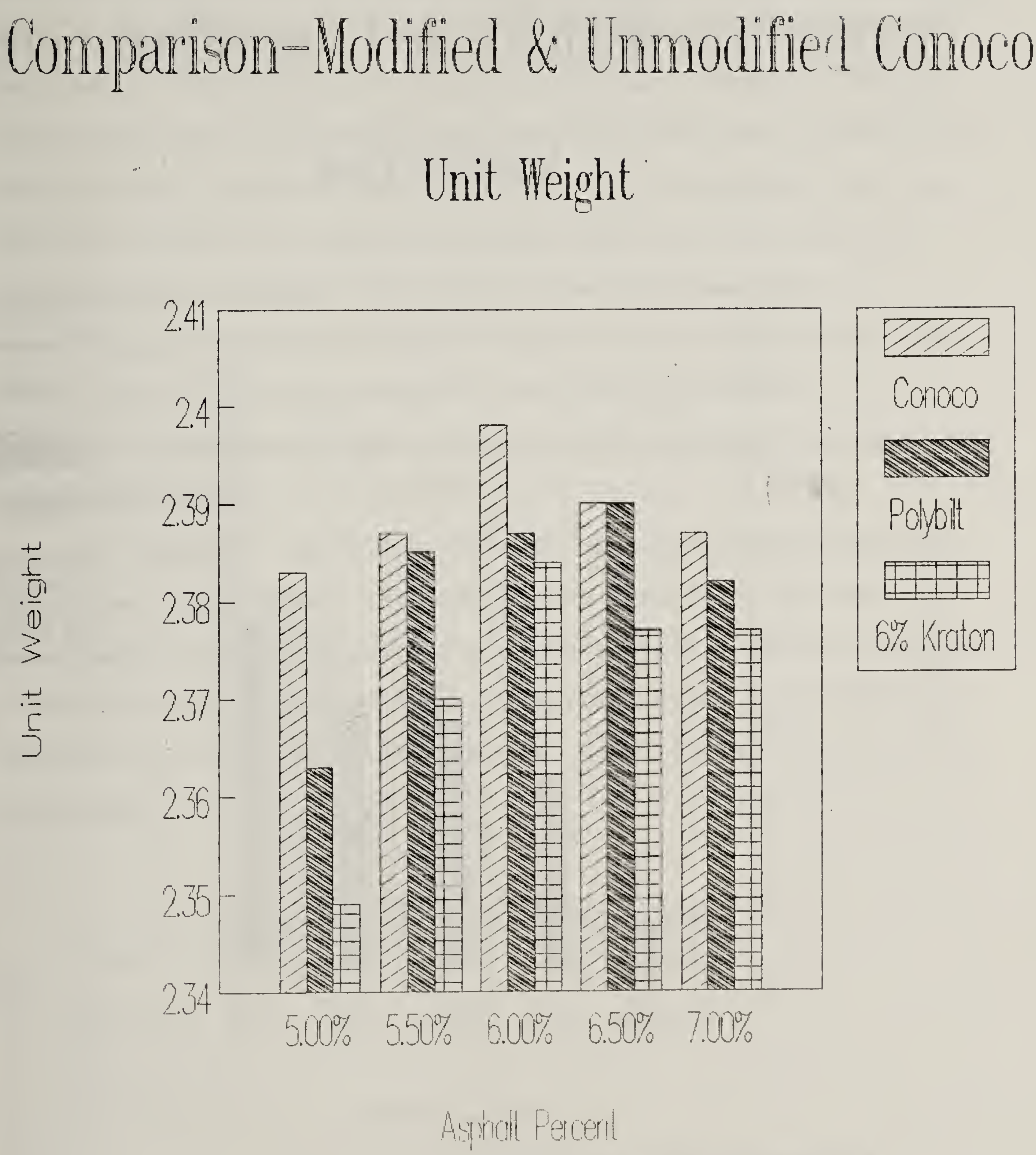

Figure 17. Comparison of Unit Weight with Modified and Unmodified Conoco

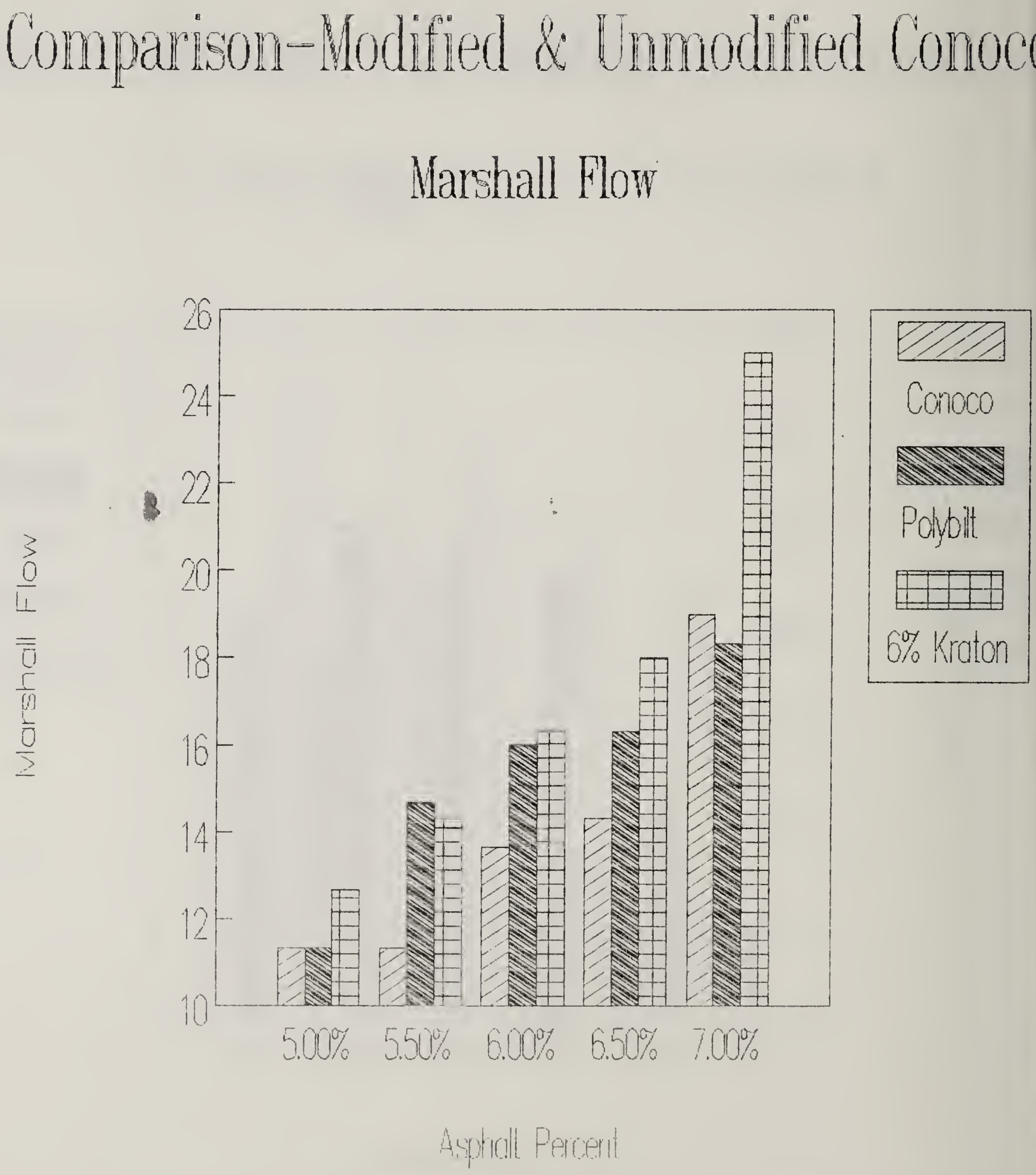

Figure 16. Comparison of Flow with Modified and Unmodified Conoco

the F-test which considers variance. Table F-values were obtained from statistics texts and dependent on sample size and confidence level. A 95 percent confidence level is used for comparison of data sets. Calculated and F-table values were compared. If the calculated value is greater than the value from the F-table, the variances are significantly different. If F calculated is less than the F-table, it cannot be proved that the variances are significantly different. In cases where variances were significantly different, Newman - Keuls tests were carried out using SAS to see which variable caused the difference.

Case A: Controlled Aggregate with Polybilt, Kraton-6 Modified and Unmodified Cenex.

The dependent variables stability and density parameters values were considered. The independent variables for both experiments were three levels of asphalt types (Polybilt, Kraton-6 modified and unmodified Cenex) and five levels of asphalt content (5%, 5.5%, 6%, 6.5%, and 7%). Thus, it is a 3*5 factorial experiment.

		5	5.5	6	6.5	7	(A)
(B)	Cenex						
	Polybilt Modified						
	Kraton-6 Modified						

There are three replications of observations at each asphalt

content and asphalt type totaling 45 observations. The observations are totally randomized. If A and B are treated as independent factors then the mathematical model will be

$$Y_{ijk} = U + A_i + B_j + AB_{ij} + E_{k(ij)}$$

Where Y_{ijk} = Response variable stability or density

U = Mean Stability or Density common effect on all observation

A_i = Effect due to % Asphalt content

B_j = Effect due to asphalt type used in controlled aggregate

AB_{ij} = Effect due to interaction

$E_{k(ij)}$ = Random error present in each of treatment

<u>Hypothesis:</u>

The null hypothesis for the stability test is that the treatment effect is zero, that is, there is no difference in stability when using different types of asphalt or different percentage of asphalt in the controlled aggregate mixture. The equations for the null hypothesis are H^o: $A^i = 0$, H^o: $B^j = 0$, and H^o: $AB^{ij} = 0$, as both main effects are fixed.

<u>Analysis of the results:</u>

It was observed from the result in Appendix D that the effect of the asphalt content did not have a significant difference in stability and density in the three types of asphalt considered at the confidence level of 95 (Alpha = .05), except

for the density of Cenex at 7%; it was different from the other percentage of asphalt content. The stability of Kraton-6 modified Cenex is different from both Polybilt modified Cenex and unmodified Cenex. These results were based on the mean of total 9 values (3*3) for three replications and three different types of asphalt and 15 values (3*5) for three replications and 5 different percentages of asphalt content. As we are interested in the effect of a specific modifier at particular asphalt content, this result was not conclusive for our use.

One-way ANOVA analysis of type as discussed in case B and C was used in this case also. The result is presented in Appendix D. It is observed from the result that the effect of the asphalt content were not significantly different in stability and density values in three types of asphalt considered at the confidence level of 95 (Alpha = .05), except for the density of the Polybilt modified Cenex at 5% (2.358) which is significantly different from those at 6% (2.392) and 6.5% (2.383) with the difference being 0.034 and 0.025 respectively. Similarly, the type did not have a significant difference in the density values except for 6% and 5% asphalt content (2.383 and 2.354). The type did not have a significant difference in the stability values except for 7% and the rest of asphalt content (1904.6 versus 2230 to 2390).

<u>Case B. Independent variables: Aggregate type (Split and Controlled), asphalt content, and asphalt type.</u>

Three separate SAS programs were run for each three different asphalt types, unmodified Cenex, Polybilt and Kraton-6

modified Cenex. The dependent variables were stability and density. One-way ANOVA was used for each dependent variables. It has one level of treatment. The independent variables are aggregate types, split controlled and three asphalt types (unmodified, Polybilt and Kraton-6 Modified Cenex) with three replicate observations at each of independent variables, asphalt content. The observations were obtained at two different blocks. The controlled aggregate block was completely randomized whereas the split aggregate block was not randomized. Since this was blocked on split aggregate, that is, the observations were not randomized, there was no physical interaction. The mathematical model for each asphalt content is:

$$Y_{ij} = U + A_i + E_{(ij)}$$

Where Y_{ijk} = Response variable stability or density from observation i and aggregate j

A_i = Effect due to aggregate type (split or controlled)

U = Mean stability or density for all types and content of asphalt

$E_{(ij)}$ = Random error present in the i^{th} observation on the j^{th} treatment.

The SAS result is presented in Appendix D. The result for Cenex shows that both density and stability were significantly different between controlled aggregate and split aggregate; except for the stability at 5.5%, 6% and 7% asphalt content, there differences were 399.6 (2330.3-1930.7), 9.7 (2036.7-2027), and 245(2202-1957) respectively. For density the difference at

6.5% was 0.023 (2.369-2.346).

Note that significant differences were observed where the difference of stability values was greater than 400 and the difference of density was greater than .024 at confidence level of 95%. Similarly, for Kraton-6 modified Cenex, the result shows that both density and stability, between the controlled and split aggregate, are significantly different, except for the stability at 5%, 5.5%, 6%, and 6.5% asphalt content, their differences were 1.3(2306-2304.7), 141(2316.7-2175.7), 16.4(2274-2258.3), and 110(2326.7-2216.7) respectively. For the Polybilt modified Cenex, the result shows that both density and stability are significantly different between the split and controlled aggregate except for stability at 5%, 6.5%, and 7% asphalt content, their differences were 410.3, 336, and 203.7 respectively. And for the density at 7% difference was .025. Critical range for Polybilt modified Cenex was high.

Case C. Independent variable: blows (50 and 75), asphalt content and asphalt type.

One-way ANOVA was used. The experiment has one level of treatment, blow. Two type of asphalt Cenex and Conoco at five different level of asphalt content were dealt separately. Independent variables were stability and density. Three replicate samples were obtained at each asphalt content for each asphalt type. The observations were obtained at two different blocks each for a type of asphalt with five different asphalt contents. The observations were not randomized. The mathematical model at each

asphalt type and content is

$$Y_{ij} = U + A_i + E_{(ij)}$$

Where Y_{ijk} = Response variable stability or density from observation i and blow j

A_i = Effect due to blow (50 or 75)

U = Mean stability or density for all type and content of asphalt

$E_{(ij)}$ = Random error present in the i^{th} observation on the j^{th} treatment.

The SAS results are presented in Appendix E. The result for Cenex shows that both density and stability, between compaction effort of blows, were significantly different, except for density at 5.5%, and 6%, their differences between mean is .018, and .041 respectively; and for stability at 6%, and 6.5% asphalt content there differences between mean were 623, and 290 respectively. The difference between mean of density and stability at 6% are high at .041 and 623 respectively, still they are not significantly different since the critical ranges were 0.0418 and 949 respectively.

Similarly, the result for Conoco shows that both density and stability are significantly different between compaction effort of blows except for stability at 6.0%, and 6.5%, their differences between mean are 287.7, and 535.4 respectively. The difference between mean of stability at 6.5% is high still it is not significantly high enough to be significantly different, since the critical range is 705.

Conclusion

By observing the asphalt test results of 1988 and 1989 asphalt, it is concluded that the physical test parameter values of an asphalt from a single source do not change significantly. This is true for the modified asphalts with equal amounts of the modifier. However, the test parameter values are changed by the amount of modifier used, as seen in case of Kraton 4141G.

The test parameter values related to the permanent deformation characteristics of the asphalt-aggregate mixture, containing modified asphalt, improved, compared to that of unmodified, asphalt to different degrees.

The mix preparation for the modified asphalt was carried out in the same way as that of unmodified asphalt. The same temperature range for the aggregate and asphalt were used. It is observed from the repetition of the test that temperature of the mix and compaction is an important factor. The temperature of the modified asphalt must be maintained at or above 275°F for smooth flow of asphalt. The learning curve of the operator is demonstrated from the deviation of the results. Any new operator should be given a break-in period before he is fully made responsible. It has been proved that Marshall results depend on the equipment and operator.

Aggregate gradation is another important factor. The minus #200 size fines could cause differences in optimum asphalt content, void ratio, density, and stability and flow parameters of Marshall mix design. The modified asphalt reflects the same kind of responses to gradation of aggregate as unmodified asphalt. While, split aggregate may represent the field condition, it may be erroneous to determine the Marshall mix design values based on it. For uniformity and repeatability, all Marshall mix design must be based on the controlled aggregate. The specification based on the controlled aggregate is the one that should be strived for in the field, also. In case the field application does not meet the specification, the parameter value of void ratio suffers the most. The laboratory controlled aggregate mix, both modified and unmodified, became rich with asphalt at 6.0% to 6.5%; while the split aggregate did not look rich at 6.5% to 7.0%, and required to go up to 7% asphalt to get the void ratio of 4% and below. In most cases VMA increased with asphalt content.

The compaction is another important factor effecting the Marshall mix design parameters. Higher compaction of 75 blows compared with 50 blows can cause the reduction in the optimum asphalt content and improve stability, density, void ratio and flow. Greater compaction has similar effect on the modified asphalt.

Laboratory experience has indicated that the mixing of modified asphalt is not different from unmodified asphalt, in

spite of high viscosity. Determination of optimum binder content for modified asphalt is similar to determining the binder content for any other asphalt.

From the ANOVA result of experimental design, stability and density values within 5 different percentage of asphalt contents are significantly different except for Polybilt modified Cenex with controlled aggregate. This means that it does not make a significant difference if there are changes in asphalt content say, between 5 to 6% in Polybilt modified Cenex, but it does in Kraton modified and unmodified Cenex. Again, if the mean values of all five asphalt contents are to be totaled and compared, Kraton modified asphalt is significantly different from the other two at 95% confidence level. There is a significant difference of density of modified and unmodified Cenex at 95 confidence level between controlled aggregate and split aggregate but not in stability. Similarly, there are significant differences of stability and density caused by compaction of 75 and 50 blows in Cenex and Conoco, except at 6.0% and 6.5% asphalt content.

We have used Georgia criteria of the range of +-400 for stability and +-.024 for density to be significantly different, and, thus, need to review the procedure or equipment or both, if a laboratory average exceeds the ranges, when compared with overall average. This is proved to be generally true for three number of replication of observations at significant level of 95.

The Marshall stability and flow values at optimum percent asphalt content of the 4.3% and 6% Kraton and Polybilt modified

Cenex are improved, but not significantly. The impact of Kraton rubber and Polybilt addition, as determined by Marshall stability and flow values, is negligible considering the variations normally observed with this test. Marshall parameter values of modified Conoco improved to a greater degree. Unit weight of modified asphalt is generally lowered by modification of asphalt. Void ratio is not the function of modified asphalt, but the void ratio has strong correlation with minus #200 and compaction effort. The higher Marshall stability and density are important for the control of rutting characteristics of the asphalt mixture, if it is obtained without a raise in Marshall flow. In the modified Conoco stability is improved but other values, unfavorable to rutting such as Marshall flow are also increased, while unit weight and percent air voids decreased. Based on just Marshall mix design values, it is hard to conclude whether all modifiers will improve the rutting characteristics in all asphalts.

The results of the extensive amount of Marshall testing, under varying degree of laboratory control, do indicate that the method is applicable to the design of asphalt-aggregate mixtures modified with rubber copolymers. Insight into rutting may also be gained when the information of this report is coupled with the UC, Berkeley creep and repeated load tests. Too, the procedures developed in this phase of the research will be valuable during the succeeding phases, in which mineral fillers and large rock mixes will be investigated.

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Appendix A. Raw Test Results of Marshall Methods

Appendix A. Marshall Test Data. * S for Split Aggregates.

Blow	Aggregate Gradation *	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S First	Cenex	5	1	1635	2.285
50	S First	Cenex	5	2	1372	2.295
50	S First	Cenex	5	3	1093	2.283
50	S First	Cenex	5.5	1	1118	2.269
50	S First	Cenex	5.5	2	1744	2.298
50	S First	Cenex	5.5	3	2016	2.298
50	S First	Cenex	6	1	1846	2.289
50	S First	Cenex	6	2	1586	2.289
50	S First	Cenex	6	3	2052	2.324
50	S First	Cenex	6.5	1	1744	2.340
50	S First	Cenex	6.5	2	1850	2.333
50	S First	Cenex	6.5	3	2017	2.314
50	S First	Cenex	7	1	1550	2.339
50	S First	Cenex	7	2	1274	2.305
50	S First	Cenex	7	3	1560	2.312
50	S First	Poly-Ce	5	1	2675	2.319
50	S First	Poly-Ce	5	2	2600	2.308
50	S First	Poly-Ce	5	3	2200	2.292
50	S First	Poly-Ce	5.5	1	2912	2.342
50	S First	Poly-Ce	5.5	2	2650	2.300
50	S First	Poly-Ce	5.5	3	2964	2.339
50	S First	Poly-Ce	6	1	2756	2.330
50	S First	Poly-Ce	6	2	2400	2.307
50	S First	Poly-Ce	6	3	1944	2.318
50	S First	Poly-Ce	6.5	1	2704	2.367
50	S First	Poly-Ce	6.5	2	2650	2.373
50	S First	Poly-Ce	6.5	3	3350	2.368
50	S First	Poly-Ce	7	1	2112	2.358
50	S First	Poly-Ce	7	2	2180	2.353
50	S First	Poly-Ce	7	3	2200	2.359
50	S First	Kr(4.3)-Ce	5	1	2548	2.280
50	S First	Kr(4.3)-Ce	5	2	1662	2.269
50	S First	Kr(4.3)-Ce	5	3	1975	2.307
50	S First	Kr(4.3)-Ce	5.5	1	2522	2.314
50	S First	Kr(4.3)-Ce	5.5	2	2131	2.319
50	S First	Kr(4.3)-Ce	5.5	3	2239	2.315
50	S First	Kr(4.3)-Ce	6	1	2000	2.299
50	S First	Kr(4.3)-Ce	6	2	2679	2.314
50	S First	Kr(4.3)-Ce	6	3	1826	2.285
50	S First	Kr(4.3)-Ce	6.5	1	2520	2.310
50	S First	Kr(4.3)-Ce	6.5	2	2453	2.311
50	S First	Kr(4.3)-Ce	6.5	3	3250	2.328
50	S First	Kr(4.3)-Ce	7	1	2889	2.339
50	S First	Kr(4.3)-Ce	7	2	2625	2.342
50	S First	Kr(4.3)-Ce	7	3	2544	2.337
50	S First	Conoco	5	1	1118	2.305
50	S First	Conoco	5	2	1482	2.272
50	S First	Conoco	5	3	1335	2.272

Blow	Aggregate Gradation *		Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S	First	Conoco	5.5	1	1512	2.288
50	S	First	Conoco	5.5	2	1601	2.293
50	S	First	Conoco	5.5	3	1525	2.284
50	S	First	Conoco	6	1	1575	2.349
50	S	First	Conoco	6	2	1800	2.368
50	S	First	Conoco	6	3	2236	2.374
50	S	First	Conoco	6.5	1	1368	2.302
50	S	First	Conoco	6.5	2	1600	2.295
50	S	First	Conoco	6.5	3	2250	2.357
50	S	First	Conoco	7	1	1869	2.336
50	S	First	Conoco	7	2	1172	2.332
50	S	First	Conoco	7	3	1975	2.334
50	S	First	Poly-Co	5	1	2904	2.302
50	S	First	Poly-Co	5	2	2832	2.300
50	S	First	Poly-Co	5	3	2976	2.309
50	S	First	Poly-Co	5.5	1	3614	2.343
50	S	First	Poly-Co	5.5	2	3024	2.343
50	S	First	Poly-Co	5.5	3	2760	2.315
50	S	First	Poly-Co	6	1	2450	2.317
50	S	First	Poly-Co	6	2	2808	2.310
50	S	First	Poly-Co	6	3	3543	2.357
50	S	First	Poly-Co	6.5	1	2756	2.374
50	S	First	Poly-Co	6.5	2	3224	2.374
50	S	First	Poly-Co	6.5	3	2990	2.378
50	S	First	Poly-Co	7	1	2712	2.344
50	S	First	Poly-Co	7	2	2550	2.365
50	S	First	Poly-Co	7	3	2800	2.362
50	S	First	Kr(4.3)-Co	5	1	2652	2.343
50	S	First	Kr(4.3)-Co	5	2	2643	2.334
50	S	First	Kr(4.3)-Co	5	3	2625	2.307
50	S	First	Kr(4.3)-Co	5.5	1	1296	2.261
50	S	First	Kr(4.3)-Co	5.5	2	2275	2.306
50	S	First	Kr(4.3)-Co	5.5	3	2444	2.283
50	S	First	Kr(4.3)-Co	6	1	2223	2.299
50	S	First	Kr(4.3)-Co	6	2	2289	2.312
50	S	First	Kr(4.3)-Co	6	3	2225	2.283
50	S	First	Kr(4.3)-Co	6.5	1	2000	2.345
50	S	First	Kr(4.3)-Co	6.5	2	2860	2.357
50	S	First	Kr(4.3)-Co	6.5	3	3042	2.347
50	S	First	Kr(4.3)-Co	7	1	2600	2.369
50	S	First	Kr(4.3)-Co	7	2	2850	2.351
50	S	First	Kr(4.3)-Co	7	3	2375	2.370

* S for Split Aggregate

Blow	*	Aggregate Gradation	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S	Second	Cenex	5	1	2174	2.334
50	S	Second	Cenex	5	2	2976	2.354
50	S	Second	Cenex	5	3	2256	2.336
50	S	Second	Cenex	5.5	1	2600	2.311
50	S	Second	Cenex	5.5	2	2522	2.324
50	S	Second	Cenex	5.5	3	2522	2.308
50	S	Second	Cenex	6	1	2730	2.371
50	S	Second	Cenex	6	2	2522	2.371
50	S	Second	Cenex	6	3	2834	2.364
50	S	Second	Cenex	6.5	1	2775	2.368
50	S	Second	Cenex	6.5	2	2575	2.383
50	S	Second	Cenex	6.5	3	2525	2.338
50	S	Second	Cenex	7	1	2475	2.375
50	S	Second	Cenex	7	2	2800	2.350
50	S	Second	Cenex	7	3	1875	2.362
50	S	Second	Poly-Ce	5	1	2600	2.338
50	S	Second	Poly-Ce	5	2	1908	2.263
50	S	Second	Poly-Ce	5	3	2425	2.294
50	S	Second	Poly-Ce	5.5	1	2139	2.311
50	S	Second	Poly-Ce	5.5	2	2925	2.341
50	S	Second	Poly-Ce	5.5	3	2832	2.332
50	S	Second	Poly-Ce	6	1	2675	2.347
50	S	Second	Poly-Ce	6	2	2098	2.302
50	S	Second	Poly-Ce	6	3	2475	2.300
50	S	Second	Poly-Ce	6.5	1	2704	2.369
50	S	Second	Poly-Ce	6.5	2	2150	2.371
50	S	Second	Poly-Ce	6.5	3	2575	2.360
50	S	Second	Poly-Ce	7	1	2304	2.323
50	S	Second	Poly-Ce	7	2	2600	2.351
50	S	Second	Poly-Ce	7	3	2280	2.332
50	S	Second	Kr(4.3)-Ce	5	1	2444	2.355
50	S	Second	Kr(4.3)-Ce	5	2	2775	2.327
50	S	Second	Kr(4.3)-Ce	5	3	2375	2.341
50	S	Second	Kr(4.3)-Ce	5.5	1	2522	2.348
50	S	Second	Kr(4.3)-Ce	5.5	2	2236	2.352
50	S	Second	Kr(4.3)-Ce	5.5	3	2400	2.330
50	S	Second	Kr(4.3)-Ce	6	1	2875	2.360
50	S	Second	Kr(4.3)-Ce	6	2	2730	2.360
50	S	Second	Kr(4.3)-Ce	6	3	2418	2.378
50	S	Second	Kr(4.3)-Ce	6.5	1	2875	2.354
50	S	Second	Kr(4.3)-Ce	6.5	2	2875	2.350
50	S	Second	Kr(4.3)-Ce	6.5	3	3016	2.360
50	S	Second	Kr(4.3)-Ce	7	1	2616	2.379
50	S	Second	Kr(4.3)-Ce	7	2	2725	2.371
50	S	Second	Kr(4.3)-Ce	7	3	2886	2.367

* S for Split Aggregates

Blow	*	Aggregate Gradation	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S	Second	Kr(6)-Ce	5	1	1500	2.263
50	S	Second	Kr(6)-Ce	5	2	1690	2.279
50	S	Second	Kr(6)-Ce	5	3	1775	2.296
50	S	Second	Kr(6)-Ce	5.5	1	1944	2.285
50	S	Second	Kr(6)-Ce	5.5	2	2136	2.310
50	S	Second	Kr(6)-Ce	5.5	3	1800	2.311
50	S	Second	Kr(6)-Ce	6	1	2288	2.330
50	S	Second	Kr(6)-Ce	6	2	2752	2.332
50	S	Second	Kr(6)-Ce	6	3	2508	2.337
50	S	Second	Kr(6)-Ce	6.5	1	2782	2.342
50	S	Second	Kr(6)-Ce	6.5	2	1975	2.334
50	S	Second	Kr(6)-Ce	6.5	3	2807	2.342
50	S	Second	Kr(6)-Ce	7	1	2480	2.355
50	S	Second	Kr(6)-Ce	7	2	1848	2.326
50	S	Second	Kr(6)-Ce	7	3	2562	2.323
50	S	Second	Conoco	5	1	1846	2.295
50	S	Second	Conoco	5	2	2550	2.344
50	S	Second	Conoco	5	3	2200	2.326
50	S	Second	Conoco	5.5	1	2496	2.354
50	S	Second	Conoco	5.5	2	2834	2.373
50	S	Second	Conoco	5.5	3	2700	2.378
50	S	Second	Conoco	6	1	2650	2.370
50	S	Second	Conoco	6	2	2314	2.349
50	S	Second	Conoco	6	3	2730	2.373
50	S	Second	Conoco	6.5	1	2180	2.377
50	S	Second	Conoco	6.5	2	2375	2.373
50	S	Second	Conoco	6.5	3	2704	2.373
50	S	Second	Conoco	7	1	1400	2.359
50	S	Second	Conoco	7	2	1950	2.346
50	S	Second	Conoco	7	3	2236	2.362
50	S	Second	Poly-Co	5	1	2832	2.287
50	S	Second	Poly-Co	5	2	3024	2.320
50	S	Second	Poly-Co	5	3	3150	2.304
50	S	Second	Poly-Co	5.5	1	3100	2.298
50	S	Second	Poly-Co	5.5	2	2850	2.321
50	S	Second	Poly-Co	5.5	3	3297	2.340
50	S	Second	Poly-Co	6	1	3250	2.377
50	S	Second	Poly-Co	6	2	2964	2.333
50	S	Second	Poly-Co	6	3	3225	2.351
50	S	Second	Poly-Co	6.5	1	2589	2.341
50	S	Second	Poly-Co	6.5	2	2376	2.237
50	S	Second	Poly-Co	6.5	3	2975	2.321
50	S	Second	Poly-Co	7	1	2028	2.318
50	S	Second	Poly-Co	7	2	2575	2.344
50	S	Second	Poly-Co	7	3	2375	2.349
50	S	Second	Kr(4.3)-Co	5	1	1690	2.287
50	S	Second	Kr(4.3)-Co	5	2	1752	2.290
50	S	Second	Kr(4.3)-Co	5	3	3175	2.347

* S for Split Aggregates

Blow	Aggregate Gradation	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
*						
50 S	Second	Kr(4.3)-Co	5.5	1	3079	2.386
50 S	Second	Kr(4.3)-Co	5.5	2	3224	2.380
50 S	Second	Kr(4.3)-Co	5.5	3	2700	2.356
50 S	Second	Kr(4.3)-Co	6	1	2574	2.364
50 S	Second	Kr(4.3)-Co	6	2	2664	2.363
50 S	Second	Kr(4.3)-Co	6	3	3075	2.380
50 S	Second	Kr(4.3)-Co	6.5	1	1992	2.337
50 S	Second	Kr(4.3)-Co	6.5	2	1968	2.343
50 S	Second	Kr(4.3)-Co	6.5	3	2098	2.303
50 S	Second	Kr(4.3)-Co	7	1	2075	2.350
50 S	Second	Kr(4.3)-Co	7	2	2106	2.353
50 S	Second	Kr(4.3)-Co	7	3	2300	2.345
50 S	Second	Kr(6)-Co	5	1	960	2.237
50 S	Second	Kr(6)-Co	5	2	1440	2.260
50 S	Second	Kr(6)-Co	5	3	1392	2.256
50 S	Second	Kr(6)-Co	5.5	1	1875	2.318
50 S	Second	Kr(6)-Co	5.5	2	1625	2.278
50 S	Second	Kr(6)-Co	5.5	3	1728	2.291
50 S	Second	Kr(6)-Co	6	1	2125	2.301
50 S	Second	Kr(6)-Co	6	2	1825	2.313
50 S	Second	Kr(6)-Co	6	3	1900	2.311
50 S	Second	Kr(6)-Co	6.5	1	2522	2.335
50 S	Second	Kr(6)-Co	6.5	2	2225	2.341
50 S	Second	Kr(6)-Co	6.5	3	2350	2.344
50 S	Second	Kr(6)-Co	7	1	2496	2.352
50 S	Second	Kr(6)-Co	7	2	2488	2.349
50 S	Second	Kr(6)-Co	7	3	2325	2.325

* S for Split Aggregates

Blow	Aggregate Gradation *	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S Third	Cenex	5	1	1560	2.312
50	S Third	Cenex	5	2	1584	2.289
50	S Third	Cenex	5	3	1662	2.290
50	S Third	Cenex	5.5	1	2046	2.313
50	S Third	Cenex	5.5	2	1846	2.327
50	S Third	Cenex	5.5	3	1900	2.317
50	S Third	Cenex	6	1	2098	2.311
50	S Third	Cenex	6	2	1628	2.313
50	S Third	Cenex	6	3	1776	2.307
50	S Third	Cenex	6.5	1	2000	2.336
50	S Third	Cenex	6.5	2	2255	2.348
50	S Third	Cenex	6.5	3	1826	2.354
50	S Third	Cenex	7	1	2160	2.352
50	S Third	Cenex	7	2	2262	2.358
50	S Third	Cenex	7	3	2184	2.356
50	S Third	Poly-Ce	5	1	1860	2.299
50	S Third	Poly-Ce	5	2	1704	2.288
50	S Third	Poly-Ce	5	3	1989	2.317
50	S Third	Poly-Ce	5.5	1	1550	2.287
50	S Third	Poly-Ce	5.5	2	1320	2.298
50	S Third	Poly-Ce	5.5	3	1604	2.288
50	S Third	Poly-Ce	6	1	1464	2.299
50	S Third	Poly-Ce	6	2	1352	2.287
50	S Third	Poly-Ce	6	3	1368	2.327
50	S Third	Poly-Ce	6.5	1	2126	2.342
50	S Third	Poly-Ce	6.5	2	2255	2.318
50	S Third	Poly-Ce	6.5	3	1925	2.320
50	S Third	Poly-Ce	7	1	2000	2.344
50	S Third	Poly-Ce	7	2	2448	2.366
50	S Third	Poly-Ce	7	3	2181	2.327
50	S Third	Kr(4.3)-Ce	5	1	2150	2.287
50	S Third	Kr(4.3)-Ce	5	2	1875	2.302
50	S Third	Kr(4.3)-Ce	5	3	1950	2.285
50	S Third	Kr(4.3)-Ce	5.5	1	1968	2.317
50	S Third	Kr(4.3)-Ce	5.5	2	2236	2.330
50	S Third	Kr(4.3)-Ce	5.5	3	2280	2.350
50	S Third	Kr(4.3)-Ce	6	1	1752	2.297
50	S Third	Kr(4.3)-Ce	6	2	1875	2.294
50	S Third	Kr(4.3)-Ce	6	3	2418	2.322
50	S Third	Kr(4.3)-Ce	6.5	1	1575	2.297
50	S Third	Kr(4.3)-Ce	6.5	2	1800	2.318
50	S Third	Kr(4.3)-Ce	6.5	3	1824	2.314
50	S Third	Kr(4.3)-Ce	7	1	1800	2.343
50	S Third	Kr(4.3)-Ce	7	2	1440	2.338
50	S Third	Kr(4.3)-Ce	7	3	2112	2.351
50	S Third	Kr(6)-Ce	5	1	2114	2.260
50	S Third	Kr(6)-Ce	5	2	2400	2.297
50	S Third	Kr(6)-Ce	5	3	2400	2.311

* S for Split Aggregate

Blow	Aggregate Gradation *	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S Third	Kr(6)-Ce	5.5	1	2002	2.301
50	S Third	Kr(6)-Ce	5.5	2	2200	2.307
50	S Third	Kr(6)-Ce	5.5	3	2325	2.294
50	S Third	Kr(6)-Ce	6	1	2544	2.315
50	S Third	Kr(6)-Ce	6	2	2400	2.323
50	S Third	Kr(6)-Ce	6	3	1880	2.323
50	S Third	Kr(6)-Ce	6.5	1	2352	2.330
50	S Third	Kr(6)-Ce	6.5	2	2054	2.329
50	S Third	Kr(6)-Ce	6.5	3	2574	2.329
50	S Third	Kr(6)-Ce	7	1	2448	2.338
50	S Third	Kr(6)-Ce	7	2	2289	2.341
50	S Third	Kr(6)-Ce	7	3	2398	2.352
50	S Third	Conoco	5	1	1824	2.303
50	S Third	Conoco	5	2	1725	2.277
50	S Third	Conoco	5	3	1352	2.310
50	S Third	Conoco	5.5	1	1600	2.323
50	S Third	Conoco	5.5	2	1575	2.323
50	S Third	Conoco	5.5	3	1776	2.342
50	S Third	Conoco	6	1	1826	2.367
50	S Third	Conoco	6	2	2046	2.345
50	S Third	Conoco	6	3	1744	2.319
50	S Third	Conoco	6.5	1	1083	2.340
50	S Third	Conoco	6.5	2	1325	2.356
50	S Third	Conoco	6.5	3	1664	2.349
50	S Third	Conoco	7	1	1776	2.375
50	S Third	Conoco	7	2	1675	2.364
50	S Third	Conoco	7	3	1440	2.351
50	S Third	Poly-Co	5	1	2000	2.273
50	S Third	Poly-Co	5	2	2162	2.277
50	S Third	Poly-Co	5	3	2093	2.273
50	S Third	Poly-Co	5.5	1	1800	2.297
50	S Third	Poly-Co	5.5	2	2200	2.313
50	S Third	Poly-Co	5.5	3	2100	2.307
50	S Third	Poly-Co	6	1	2139	2.315
50	S Third	Poly-Co	6	2	1898	2.308
50	S Third	Poly-Co	6	3	2158	2.303
50	S Third	Poly-Co	6.5	1	2125	2.300
50	S Third	Poly-Co	6.5	2	1950	2.299
50	S Third	Poly-Co	6.5	3	2093	2.298
50	S Third	Poly-Co	7	1	2175	2.335
50	S Third	Poly-Co	7	2	2150	2.342
50	S Third	Poly-Co	7	3	2025	2.339
50	S Third	Kr(4.3)-Co	5	1	1632	2.278
50	S Third	Kr(4.3)-Co	5	2	1950	2.295
50	S Third	Kr(4.3)-Co	5	3	1475	2.308
50	S Third	Kr(4.3)-Co	5.5	1	1800	2.316
50	S Third	Kr(4.3)-Co	5.5	2	1950	2.281
50	S Third	Kr(4.3)-Co	5.5	3	1680	2.286

* S for Split Aggregates

Blow	Aggregate Gradation *		Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	S	Third	Kr(4.3)-Co	6	1	1950	2.358
50	S	Third	Kr(4.3)-Co	6	2	1700	2.295
50	S	Third	Kr(4.3)-Co	6	3	1525	2.311
50	S	Third	Kr(4.3)-Co	6.5	1	2730	2.354
50	S	Third	Kr(4.3)-Co	6.5	2	2725	2.360
50	S	Third	Kr(4.3)-Co	6.5	3	3025	2.363
50	S	Third	Kr(4.3)-Co	7	1	2275	2.353
50	S	Third	Kr(4.3)-Co	7	2	2352	2.341
50	S	Third	Kr(4.3)-Co	7	3	1628	2.312
50	S	Third	Kr(6)-Co	5	1	2328	2.278
50	S	Third	Kr(6)-Co	5	2	2496	2.322
50	S	Third	Kr(6)-Co	5	3	2028	2.317
50	S	Third	Kr(6)-Co	5.5	1	2425	2.354
50	S	Third	Kr(6)-Co	5.5	2	2175	2.311
50	S	Third	Kr(6)-Co	5.5	3	2883	2.310
50	S	Third	Kr(6)-Co	6	1	2300	2.275
50	S	Third	Kr(6)-Co	6	2	2666	2.276
50	S	Third	Kr(6)-Co	6	3	2016	2.234
50	S	Third	Kr(6)-Co	6.5	1	3050	2.368
50	S	Third	Kr(6)-Co	6.5	2	2600	2.364
50	S	Third	Kr(6)-Co	6.5	3	2375	2.373
50	S	Third	Kr(6)-Co	7	1	1944	2.369
50	S	Third	Kr(6)-Co	7	2	2548	2.358
50	S	Third	Kr(6)-Co	7	3	2400	2.356

* S for Split Aggregates

Blow	Aggregate Gradation *	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
75 S	Third	Cenex	4.5	1	2592	2.327
75 S	Third	Cenex	4.5	2	2112	2.303
75 S	Third	Cenex	4.5	3	2280	2.327
75 S	Third	Cenex	5	1	2200	2.344
75 S	Third	Cenex	5	2	2158	2.343
75 S	Third	Cenex	5	3	2050	2.348
75 S	Third	Cenex	5.5	1	2418	2.364
75 S	Third	Cenex	5.5	2	2375	2.299
75 S	Third	Cenex	5.5	3	2450	2.349
75 S	Third	Cenex	6	1	1896	2.322
75 S	Third	Cenex	6	2	2500	2.371
75 S	Third	Cenex	6	3	2975	2.361
75 S	Third	Cenex	6.5	1	2451	2.378
75 S	Third	Cenex	6.5	2	2400	2.385
75 S	Third	Cenex	6.5	3	2100	2.381
75 S	Third	Conoco	4.5	1	1690	2.314
75 S	Third	Conoco	4.5	2	1924	2.296
75 S	Third	Conoco	4.5	3	1550	2.316
75 S	Third	Conoco	5	1	2050	2.350
75 S	Third	Conoco	5	2	2250	2.347
75 S	Third	Conoco	5	3	2288	2.359
75 S	Third	Conoco	5.5	1	2616	2.372
75 S	Third	Conoco	5.5	2	2071	2.388
75 S	Third	Conoco	5.5	3	2507	2.381
75 S	Third	Conoco	6	1	1872	2.374
75 S	Third	Conoco	6	2	2184	2.401
75 S	Third	Conoco	6	3	2423	2.401
75 S	Third	Conoco	6.5	1	2160	2.392
75 S	Third	Conoco	6.5	2	1526	2.370
75 S	Third	Conoco	6.5	3	1992	2.389

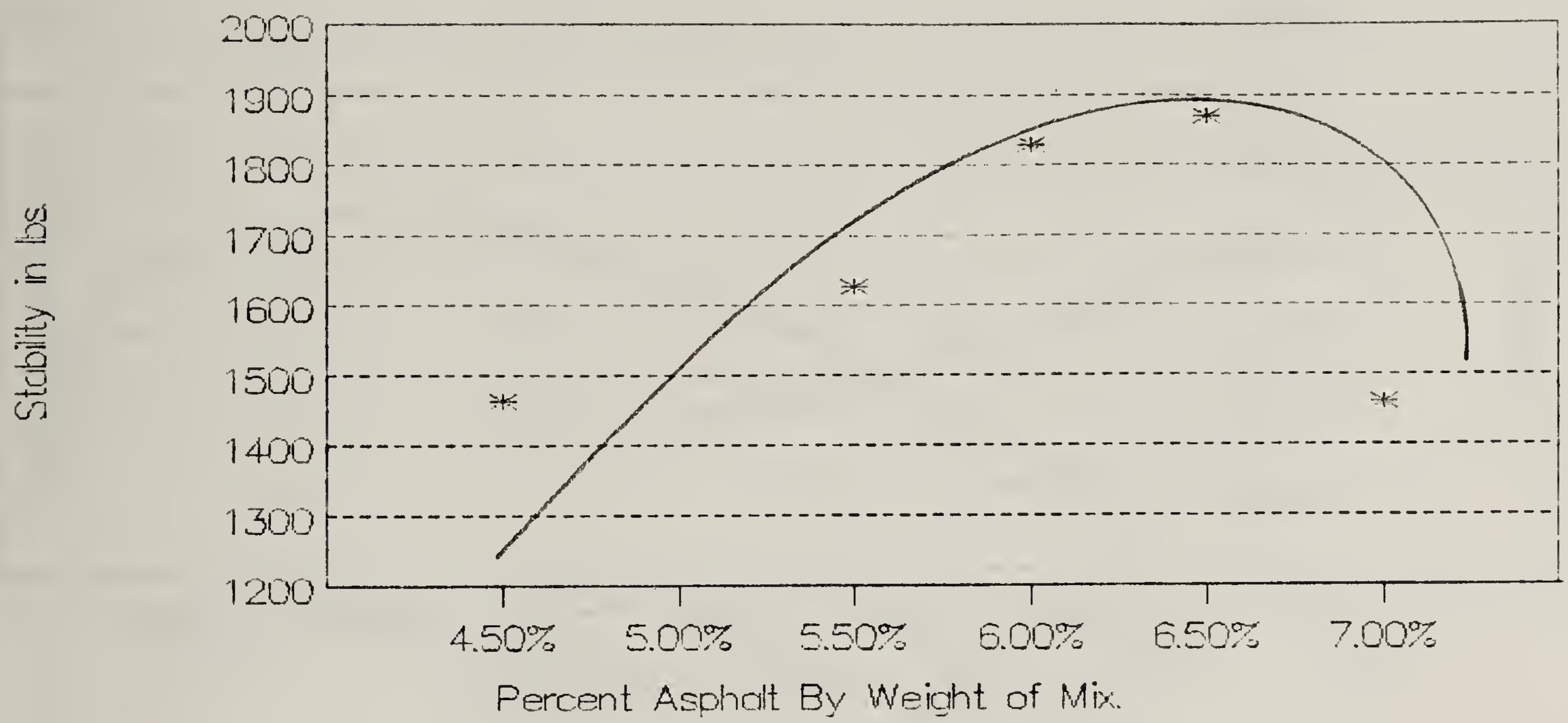
* S for Split Aggregates

Blow	Aggregate Gradation	Asphalt Type	Asphalt Content	Sample Number	Stability	Unit Weight
50	Controlled	Cenex	5	1	1975	2.350
50	Controlled	Cenex	5	2	2550	2.369
50	Controlled	Cenex	5	3	2150	2.358
50	Controlled	Cenex	5.5	1	2025	2.343
50	Controlled	Cenex	5.5	2	2184	2.403
50	Controlled	Cenex	5.5	3	2782	2.392
50	Controlled	Cenex	6	1	2470	2.386
50	Controlled	Cenex	6	2	2392	2.391
50	Controlled	Cenex	6	3	2418	2.407
50	Controlled	Cenex	6.5	1	1696	2.376
50	Controlled	Cenex	6.5	2	2256	2.339
50	Controlled	Cenex	6.5	3	2158	2.391
50	Controlled	Cenex	7	1	2050	2.383
50	Controlled	Cenex	7	2	1670	2.381
50	Controlled	Cenex	7	3	2153	2.380
50	Controlled	Poly-Ce	5	1	2184	2.356
50	Controlled	Poly-Ce	5	2	1925	2.350
50	Controlled	Poly-Ce	5	3	2675	2.369
50	Controlled	Poly-Ce	5.5	1	2325	2.370
50	Controlled	Poly-Ce	5.5	2	2075	2.383
50	Controlled	Poly-Ce	5.5	3	2875	2.379
50	Controlled	Poly-Ce	6	1	2150	2.382
50	Controlled	Poly-Ce	6	2	2730	2.398
50	Controlled	Poly-Ce	6	3	2575	2.395
50	Controlled	Poly-Ce	6.5	1	2314	2.368
50	Controlled	Poly-Ce	6.5	2	2625	2.390
50	Controlled	Poly-Ce	6.5	3	2375	2.392
50	Controlled	Poly-Ce	7	1	1872	2.377
50	Controlled	Poly-Ce	7	2	1962	2.371
50	Controlled	Poly-Ce	7	3	2184	2.365
50	Controlled	Kr(6)-Ce	5	1	1900	2.337
50	Controlled	Kr(6)-Ce	5	2	2236	2.334
50	Controlled	Kr(6)-Ce	5	3	2782	2.365
50	Controlled	Kr(6)-Ce	5.5	1	2075	2.339
50	Controlled	Kr(6)-Ce	5.5	2	2625	2.396
50	Controlled	Kr(6)-Ce	5.5	3	2250	2.343
50	Controlled	Kr(6)-Ce	6	1	2200	2.356
50	Controlled	Kr(6)-Ce	6	2	2100	2.375
50	Controlled	Kr(6)-Ce	6	3	2475	2.360
50	Controlled	Kr(6)-Ce	6.5	1	2000	2.367
50	Controlled	Kr(6)-Ce	6.5	2	2300	2.380
50	Controlled	Kr(6)-Ce	6.5	3	2350	2.365
50	Controlled	Kr(6)-Ce	7	1	1550	2.353
50	Controlled	Kr(6)-Ce	7	2	1850	2.364
50	Controlled	Kr(6)-Ce	7	3	1850	2.360

Appendix B. Test Property Curves for Hot-mix Design Data by Marshall Method

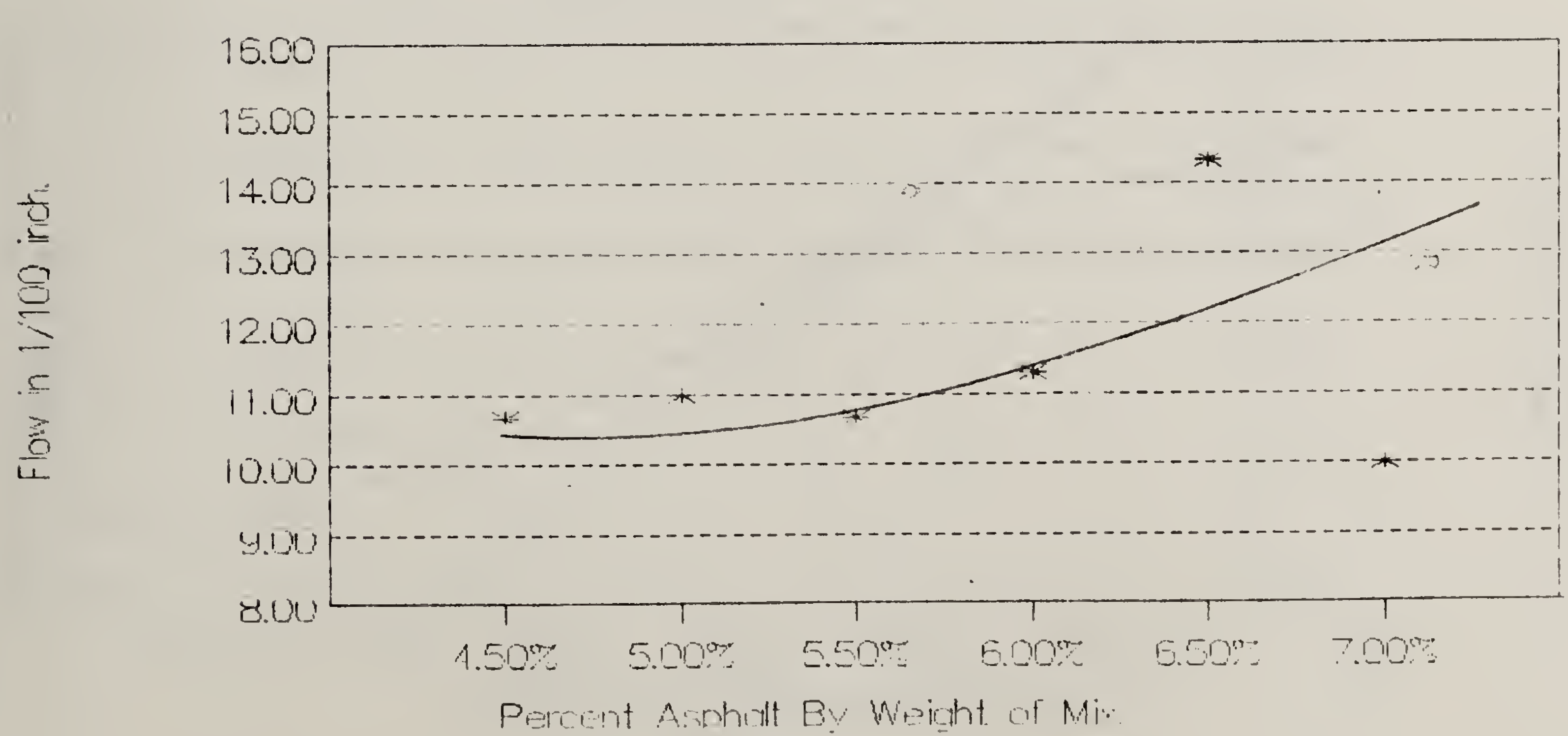
Unmodified Cenex—Stability

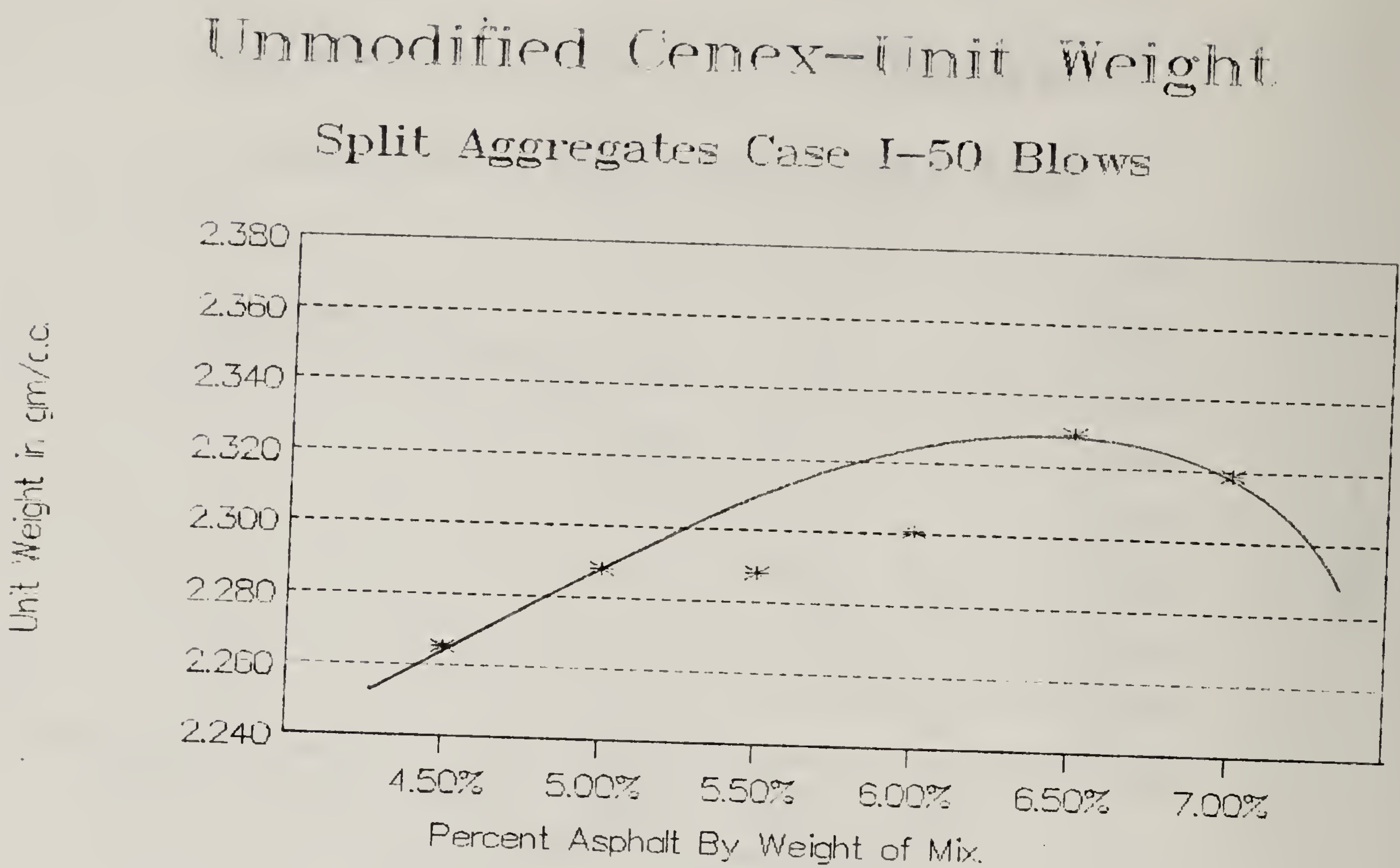
Split Aggregates Case I—50 Blows

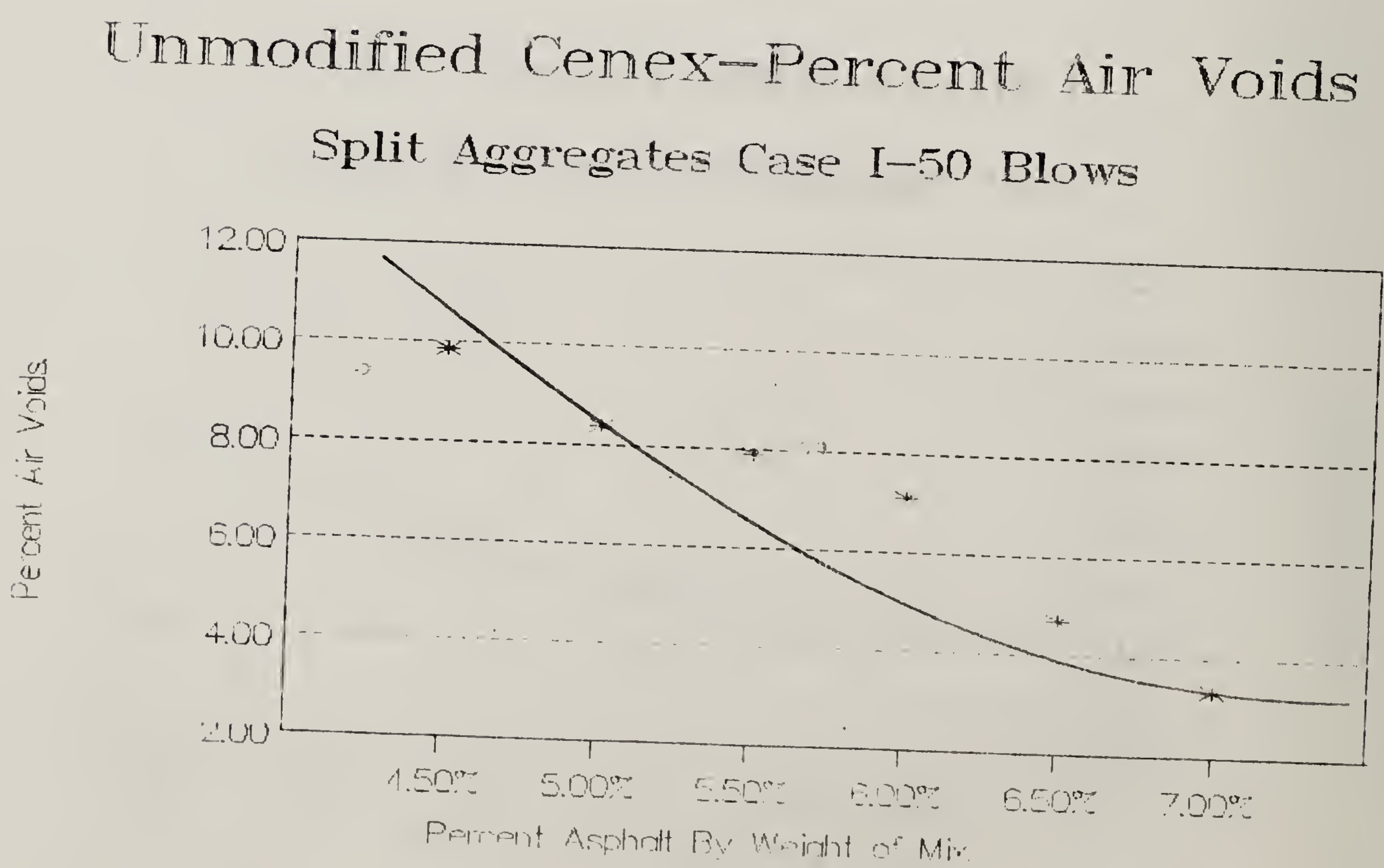


Unmodified Cenex—Flow

Split Aggregates Case I—50 Blows

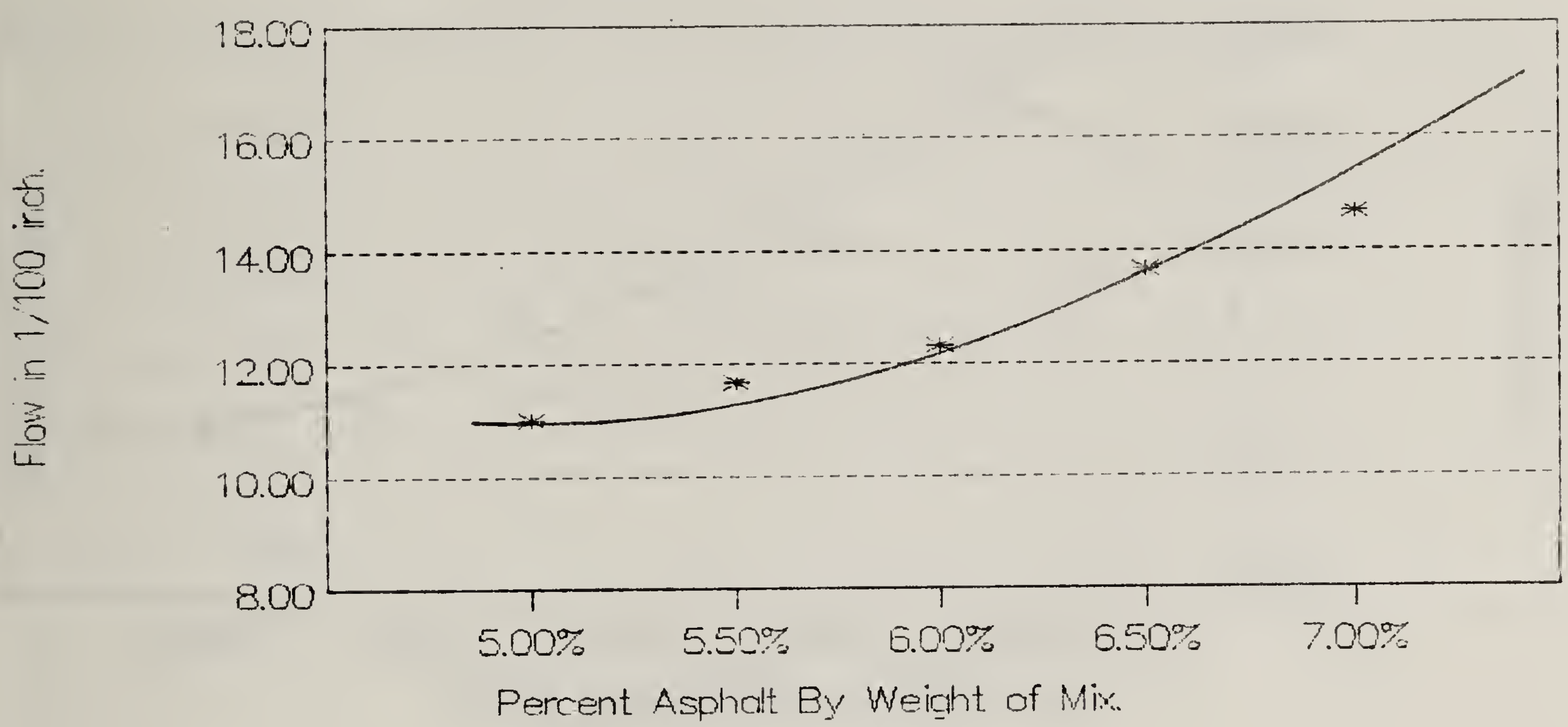



Unmodified Cenex-Unit Weight
Split Aggregates Case I-50 Blows
Unit Weight in gm/c.c.
2.380
2.360
2.340
2.320
2.300
2.280
2.260
2.240
4.50%
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Unmodified Cenex-Percent Air Voids
Split Aggregates Case I-50 Blows
Percent Air Voids
12.00
10.00
8.00
6.00
4.00
2.00
4.50%
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix

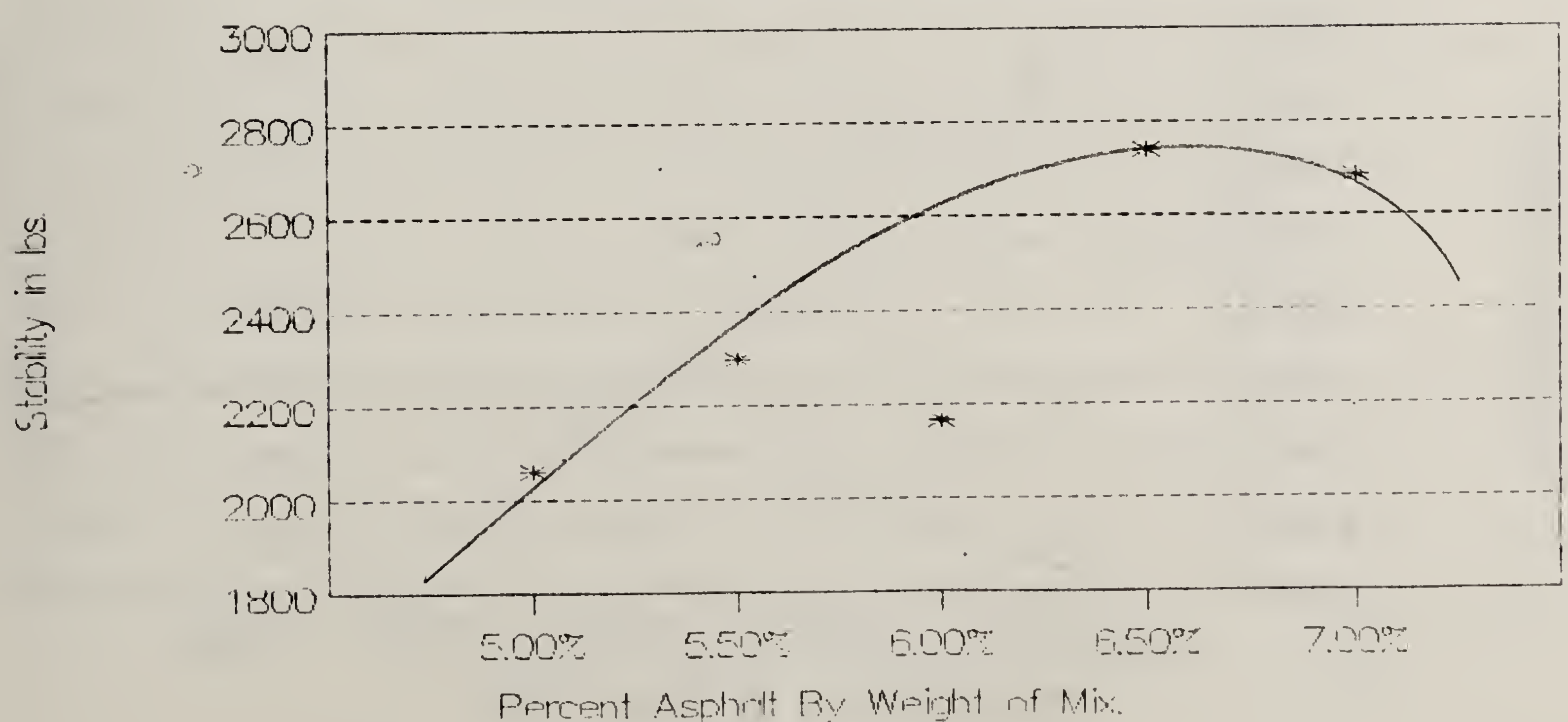
Kraton (4.3%) Mod. Cenex—Flow

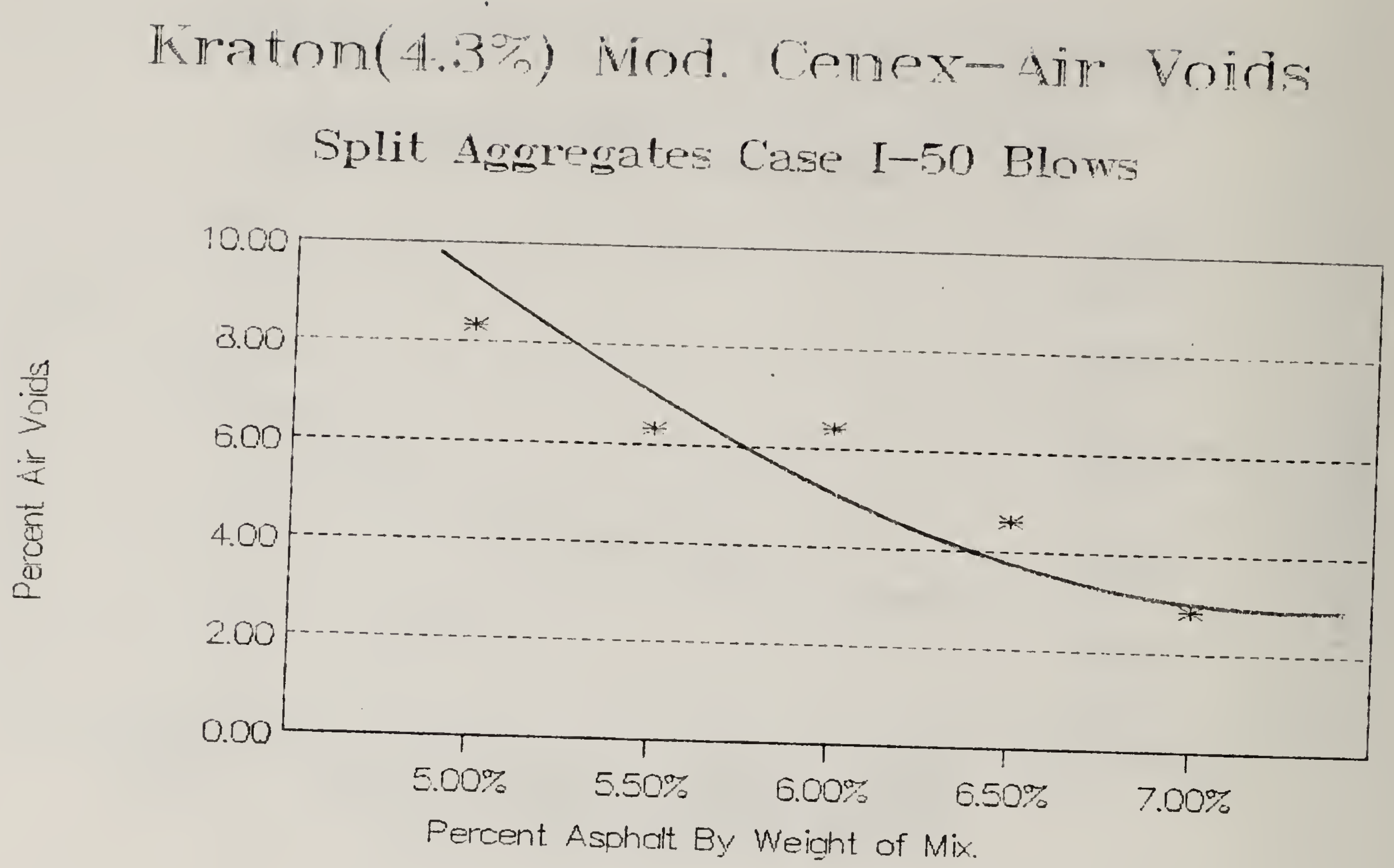
Split Aggregates Case I—50 Blows

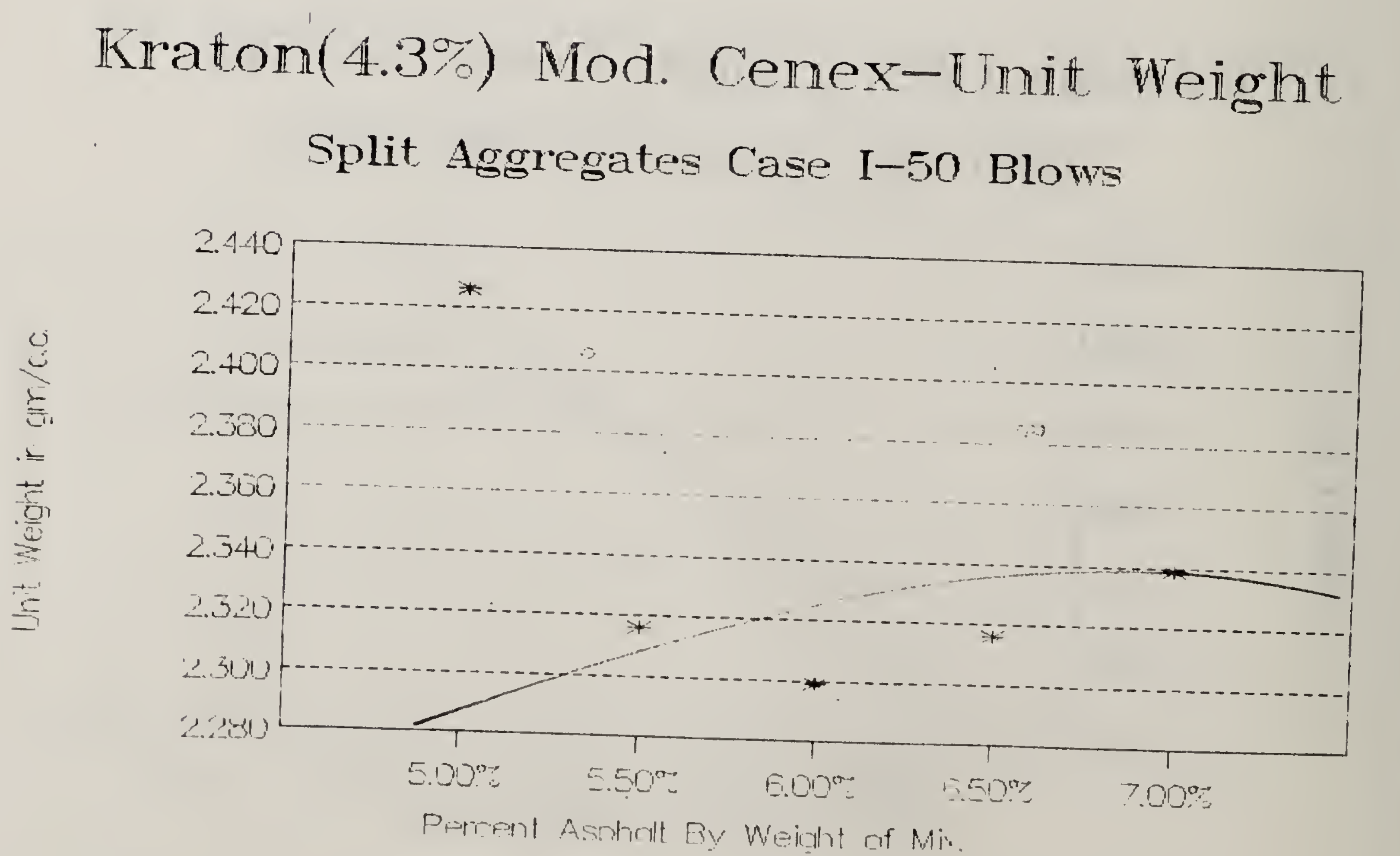


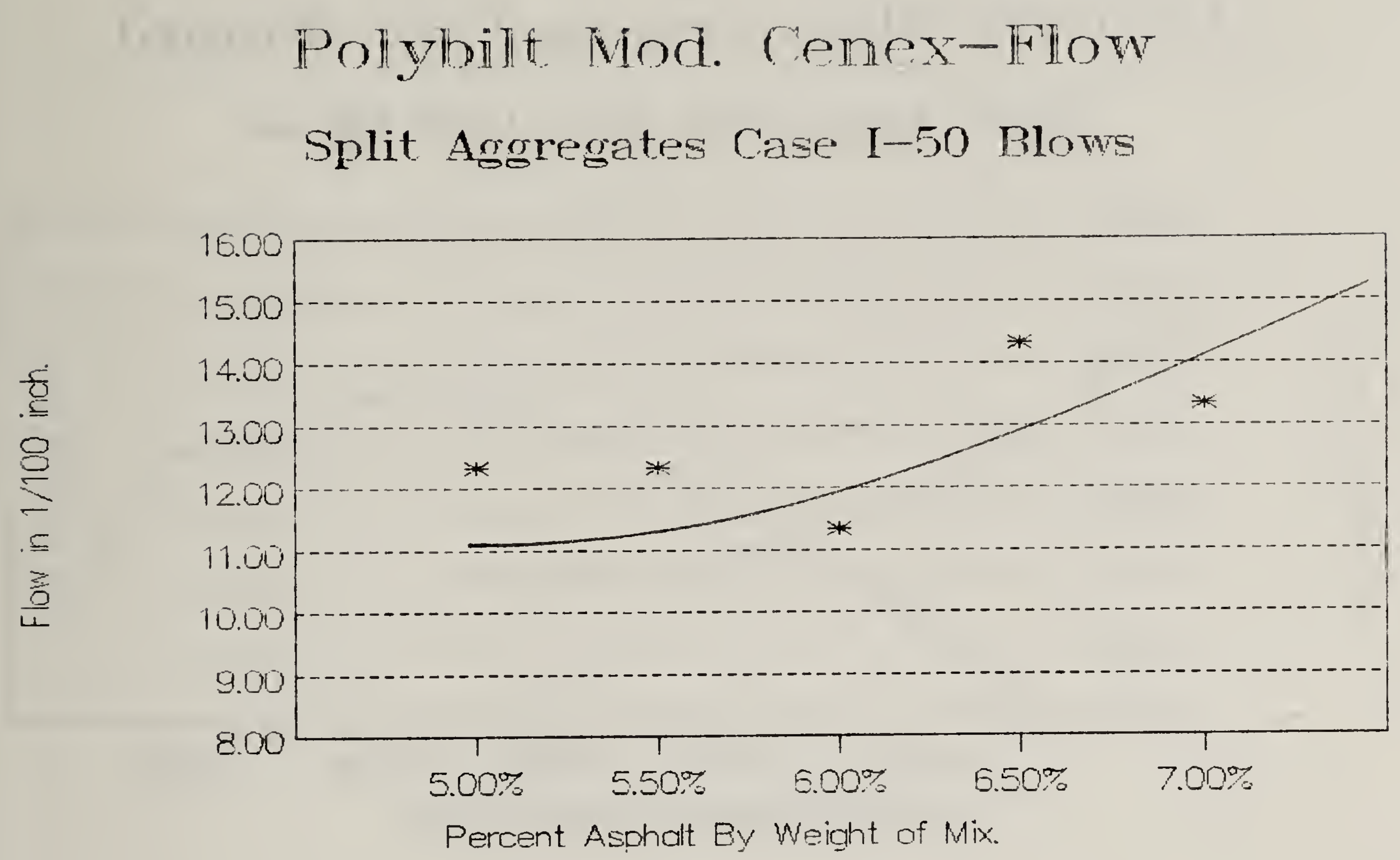
Kraton (4.3%) Mod. Cenex—Stability

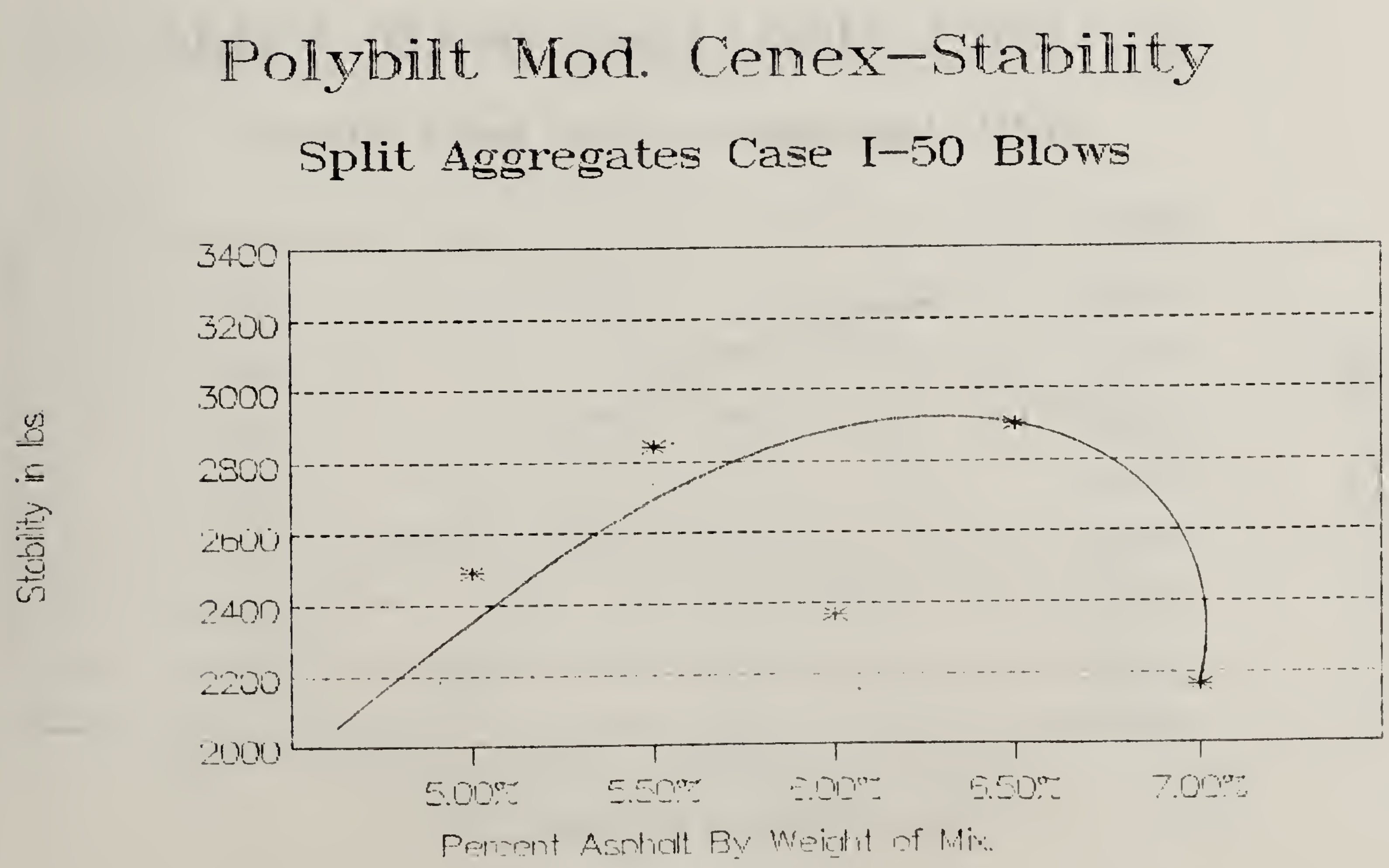
Split Aggregates Case I—50 Blows




Kraton(4.3%) Mod. Cenex-Air Voids
Split Aggregates Case I-50 Blows
Percent Air Voids
10.00
8.00
6.00
4.00
2.00
0.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

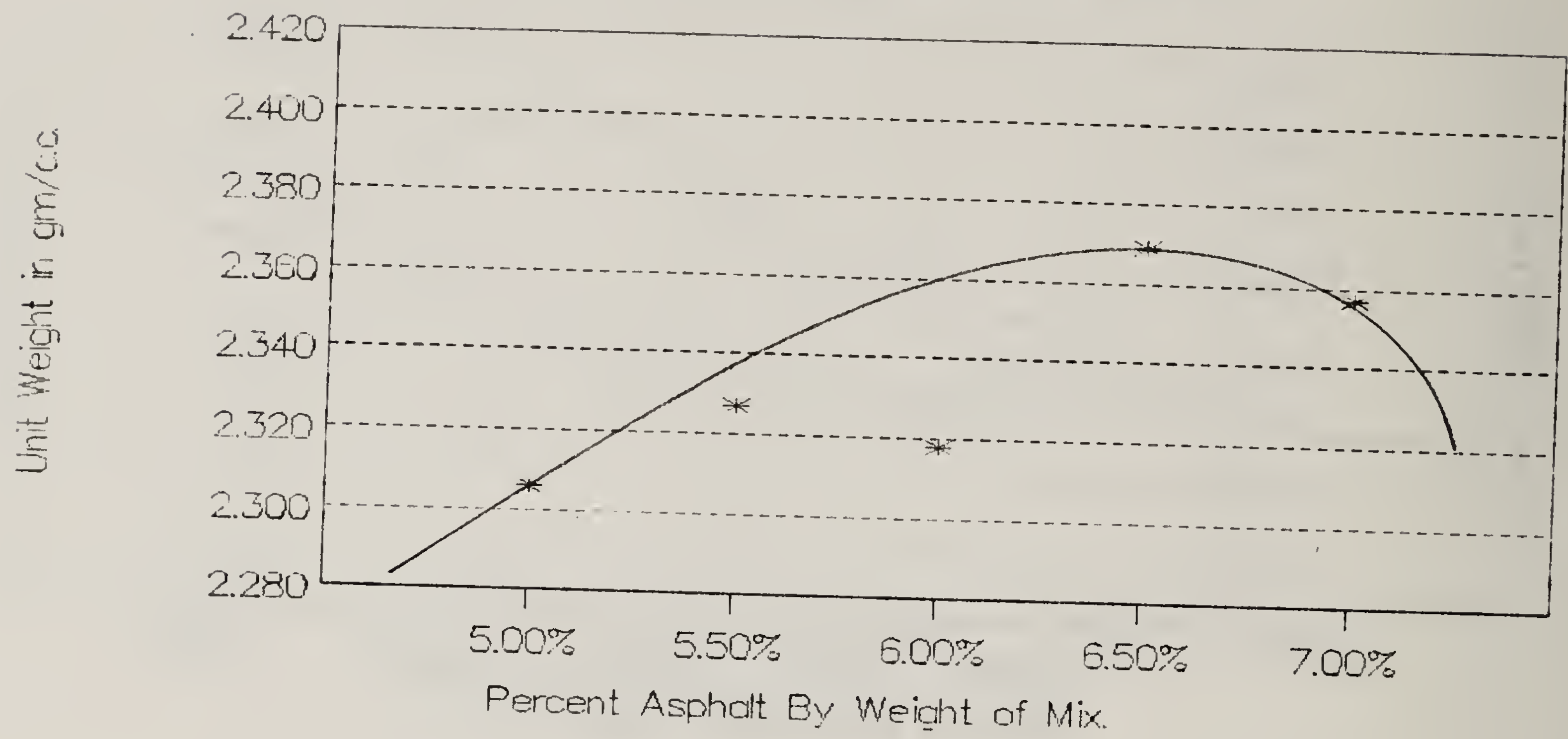

Kraton(4.3%) Mod. Cenex-Unit Weight
Split Aggregates Case I-50 Blows
Unit Weight in gm/c.c.
2.440
2.420
2.400
2.380
2.360
2.340
2.320
2.300
2.280
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Polybilt Mod. Cenex—Flow
Split Aggregates Case I—50 Blows
Flow in 1/100 inch.
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Polybilt Mod. Cenex—Stability
Split Aggregates Case I—50 Blows
Stability in lbs.
3400
3200
3000
2800
2600
2400
2200
2000
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

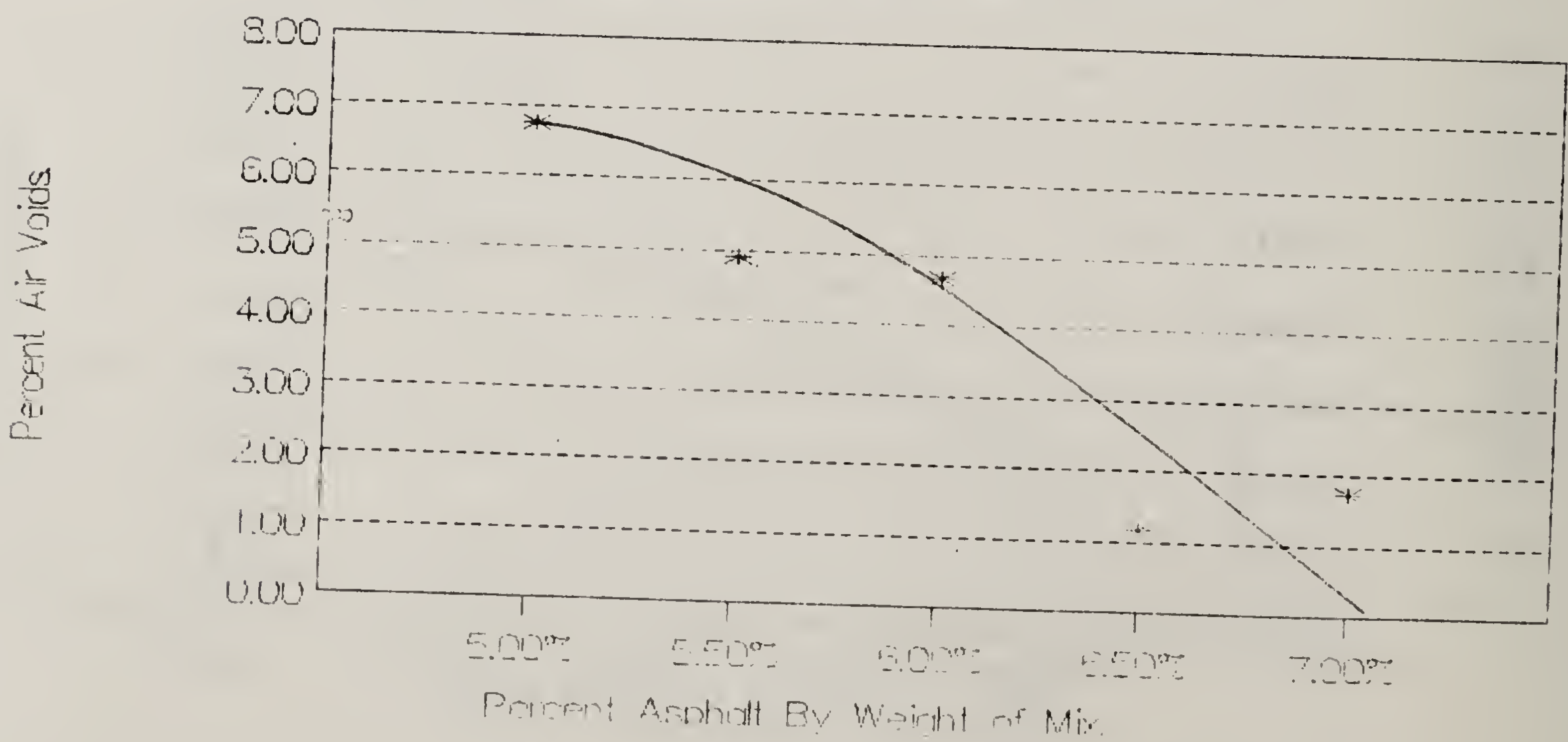
Polybilt Mod. Cenex-Unit Weight

Split Aggregates Case I-50 Blows



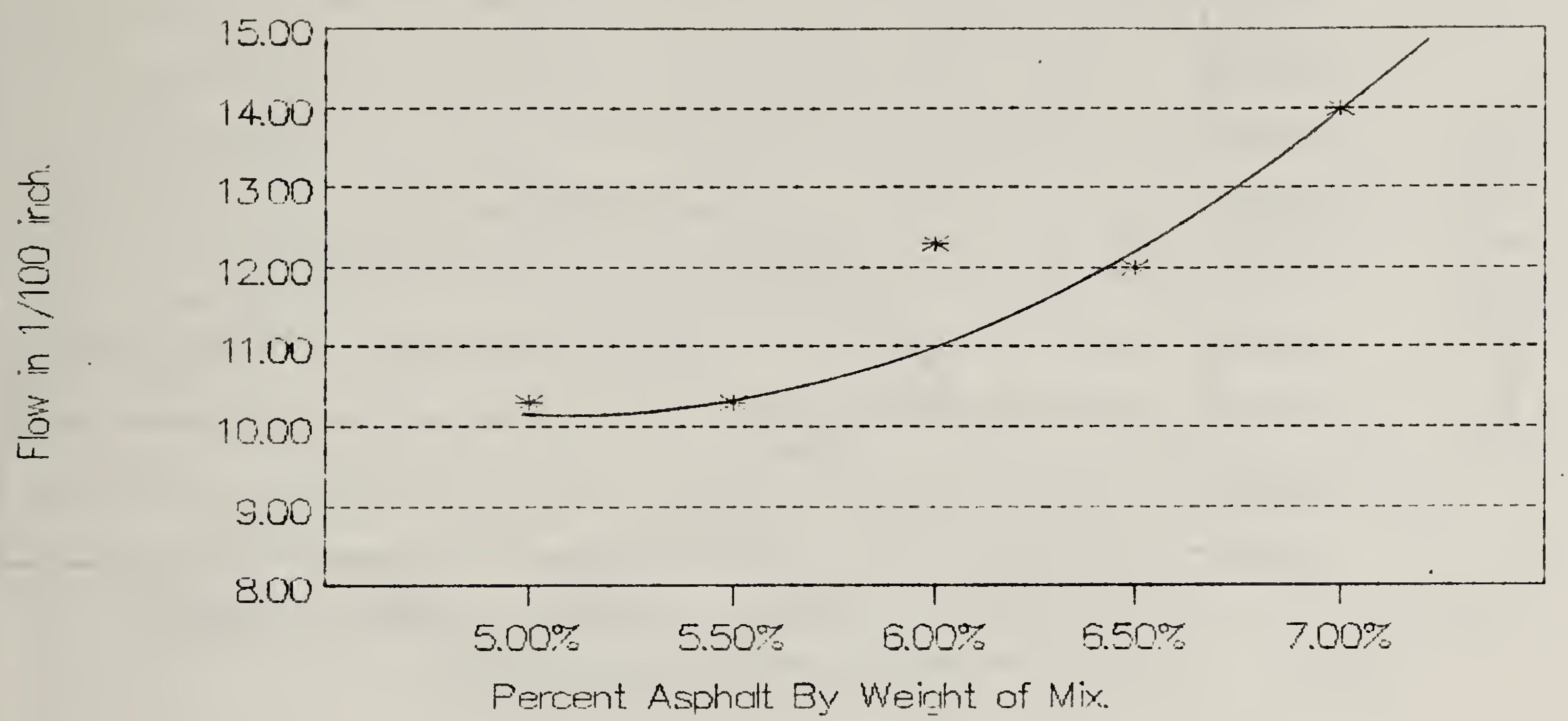
Polybilt Mod. Cenex-Air Voids

Split Aggregates Case I-50 Blows



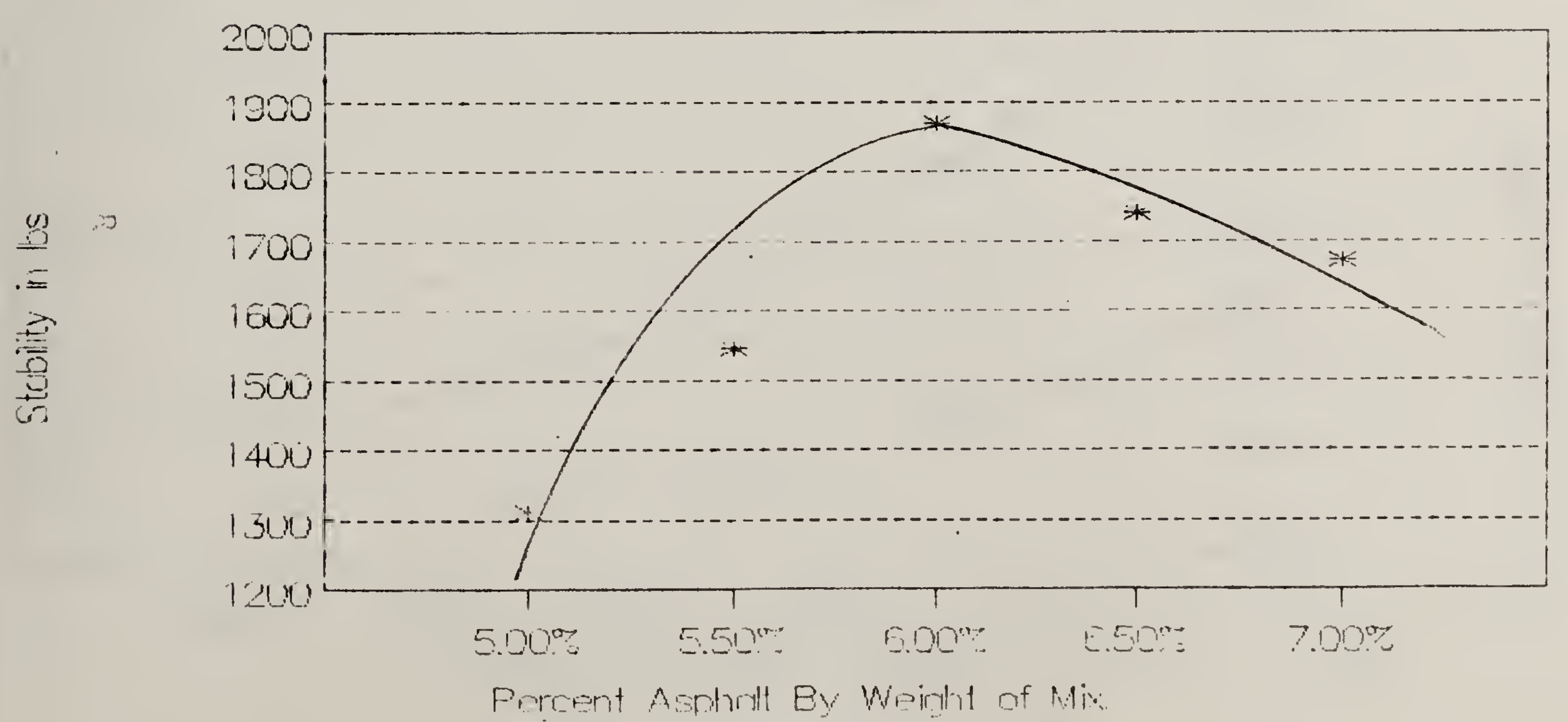
Unmodified Conoco–Flow

Split Aggregates Case I–50 Blows



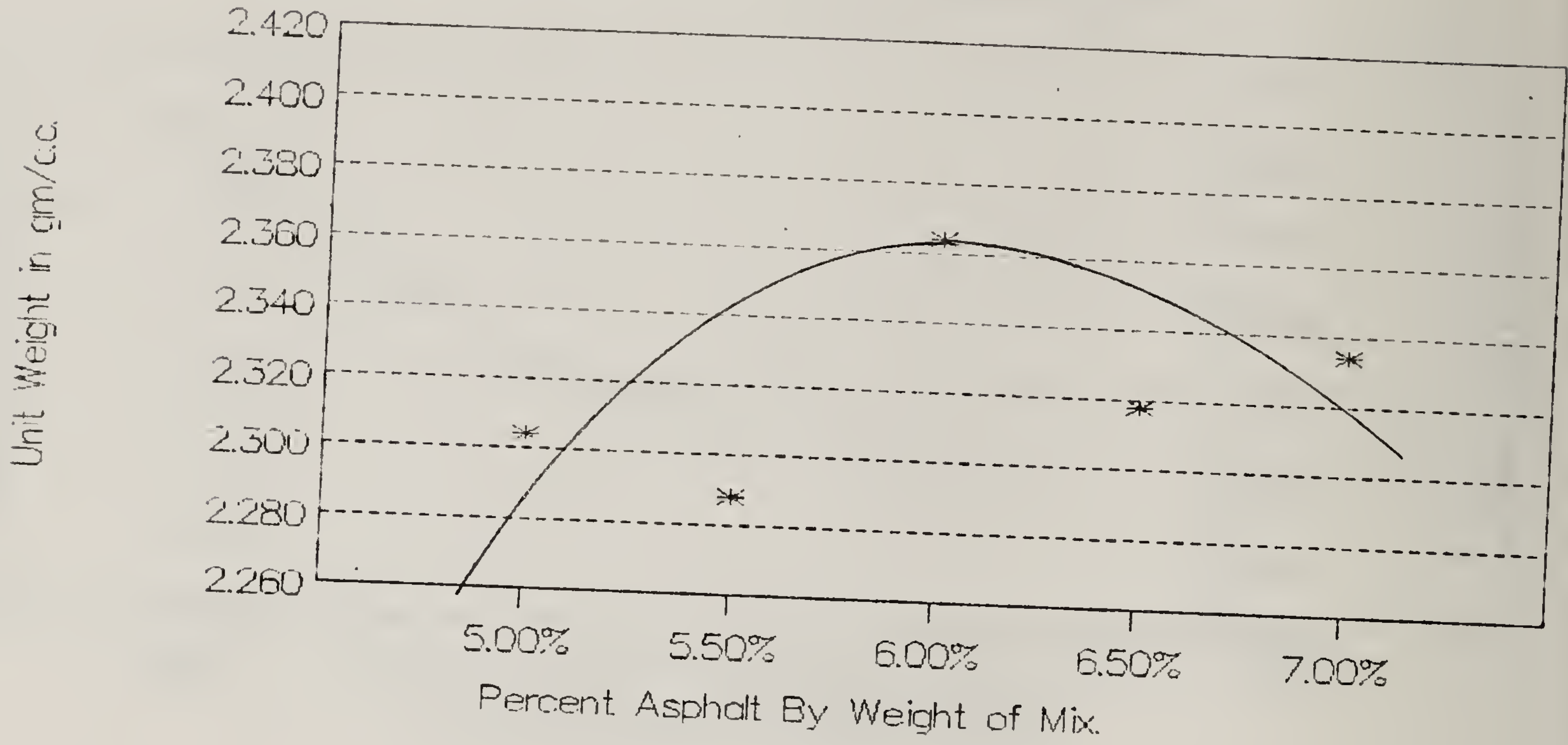
Unmodified Conoco–Stability

Split Aggregates Case I–50 Blows



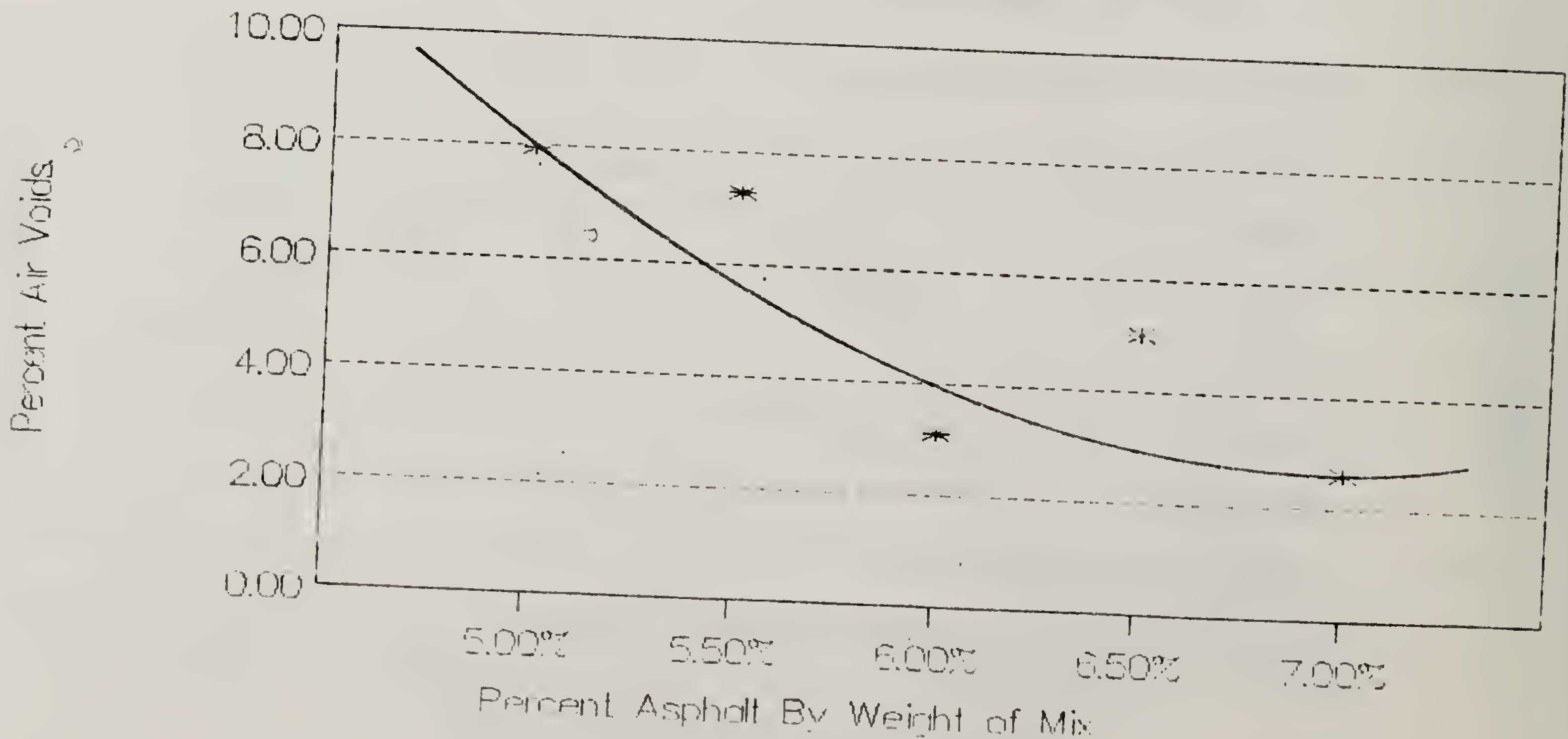
Unmodified Conoco–Unit Weight

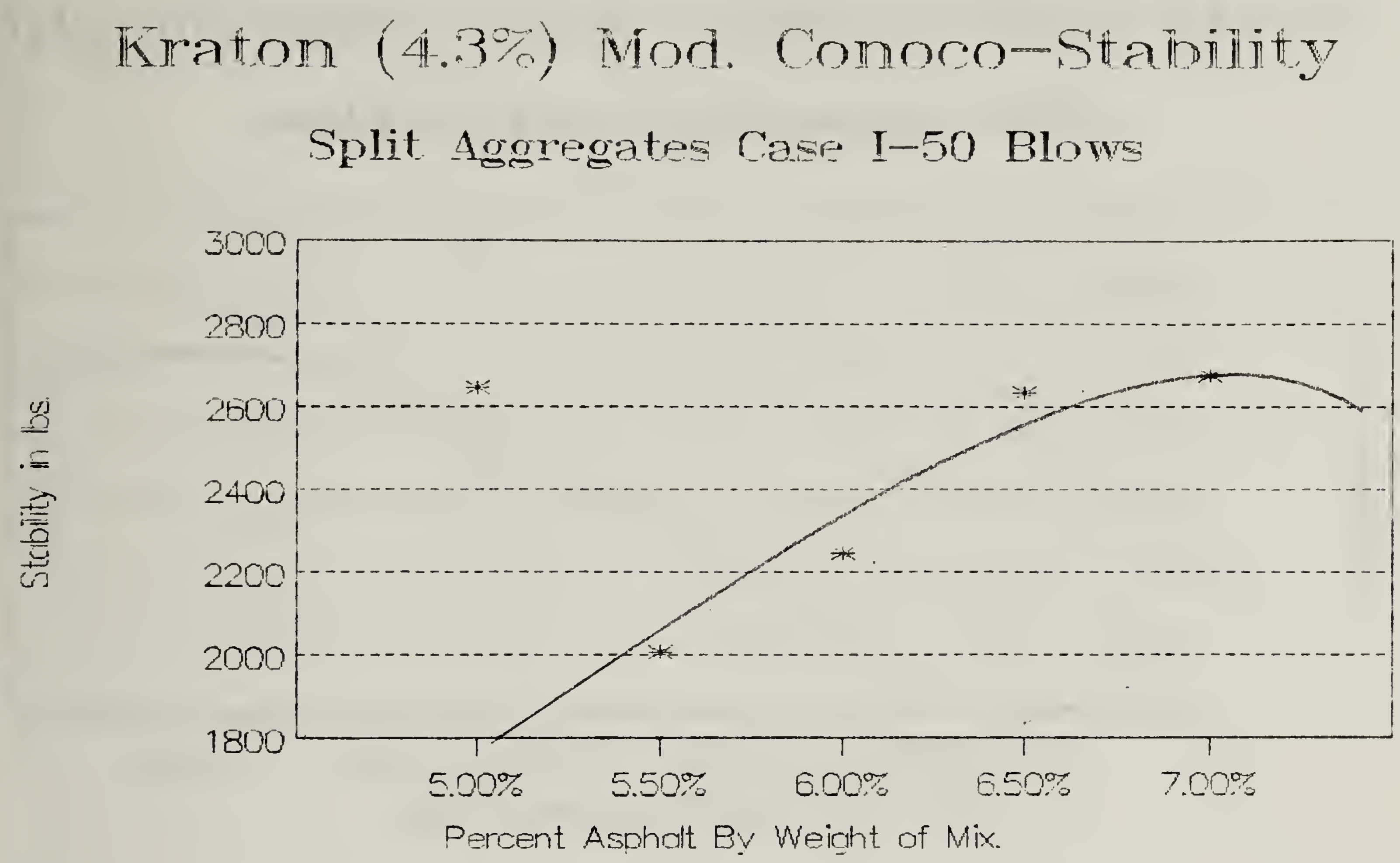
Split Aggregates Case I–50 Blows

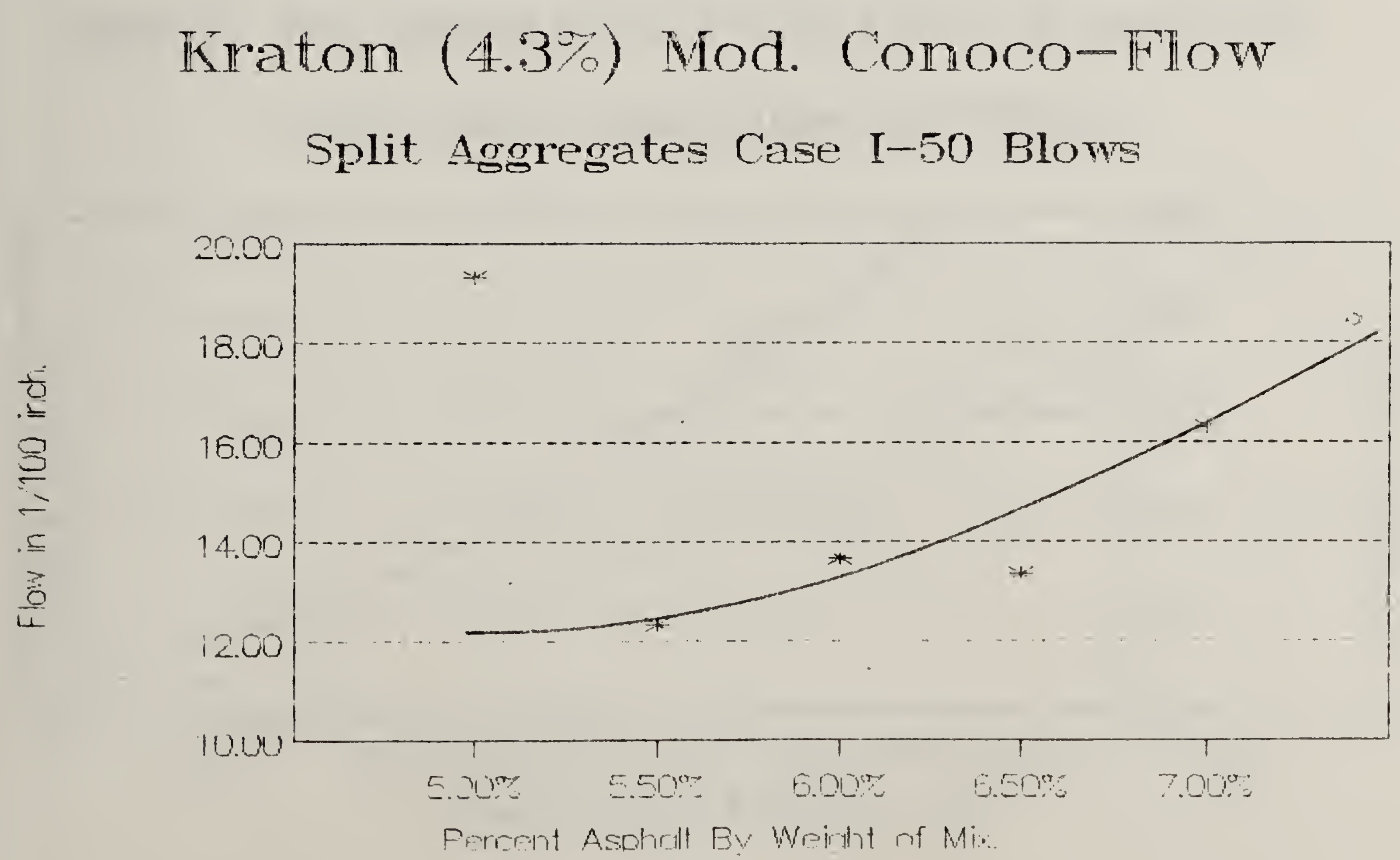


Unmodified Conoco–Percent Air Voids

Split Aggregates Case I–50 Blows

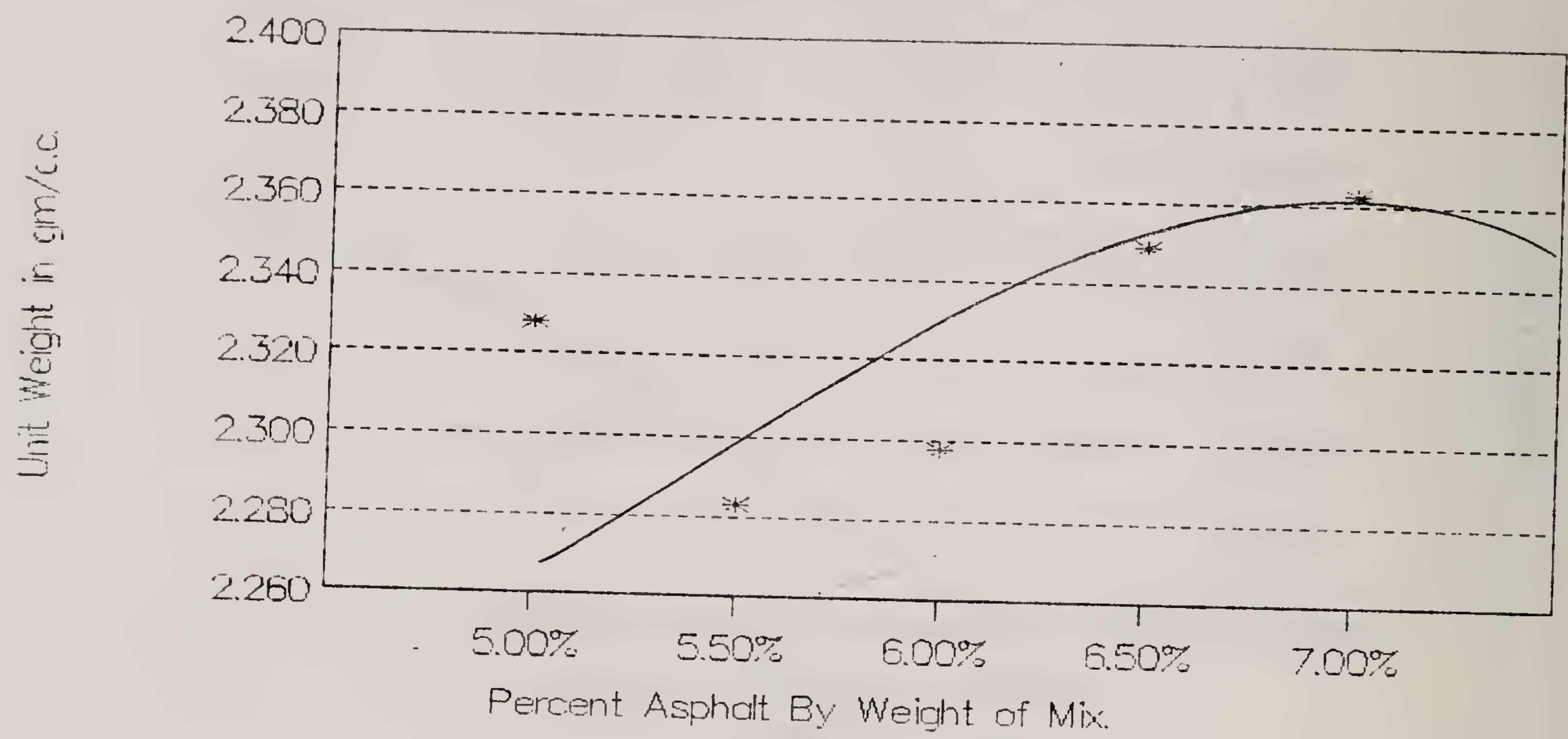



Kraton (4.3%) Mod. Conoco-Stability
Split Aggregates Case I-50 Blows
Stability in lbs.
3000
2800
2600
2400
2200
2000
1800
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Kraton (4.3%) Mod. Conoco-Flow
Split Aggregates Case I-50 Blows
Flow in 1/100 inch.
20.00
18.00
16.00
14.00
12.00
10.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

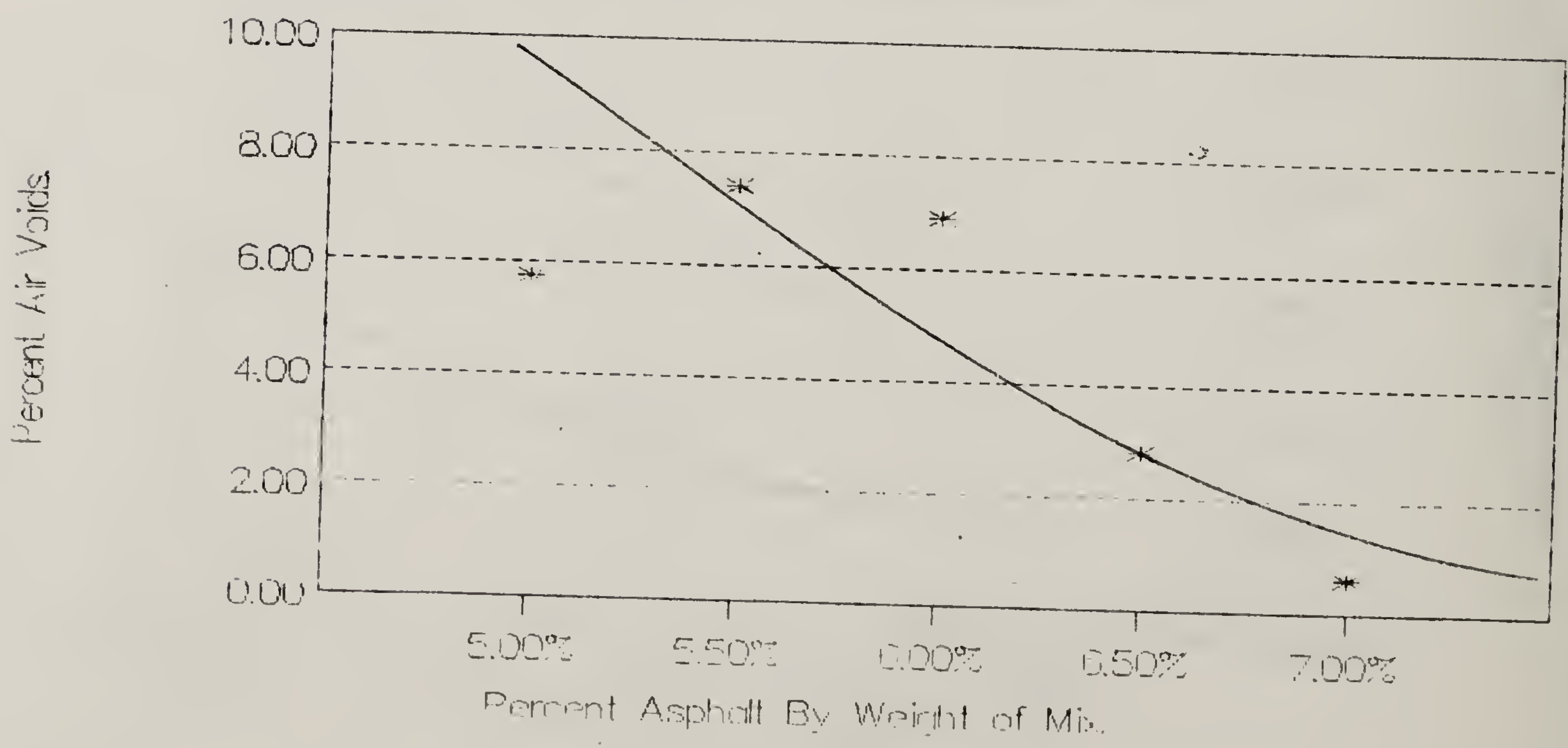
Kraton (4.3%) Mod. Conoco–Unit Weight

Split Aggregates Case I–50 Blows



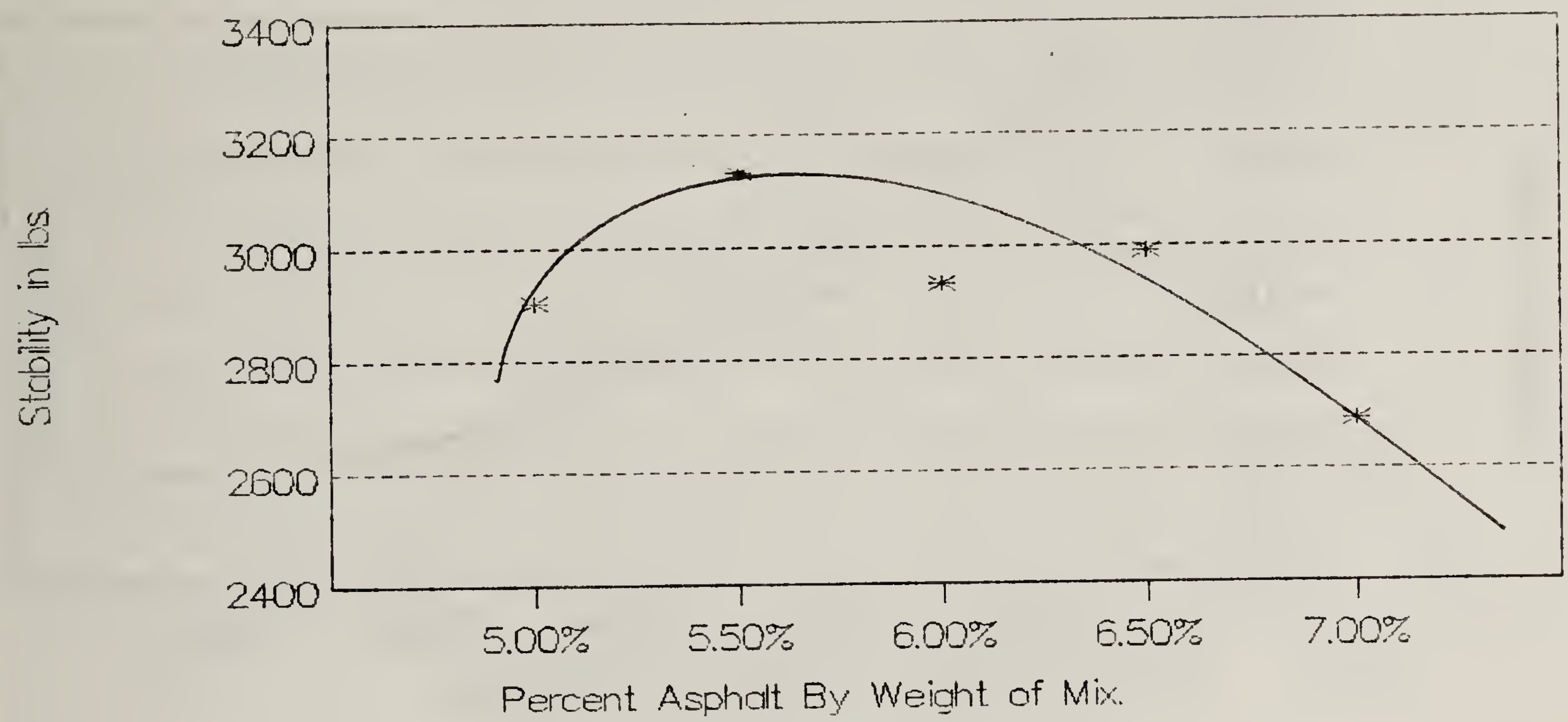
Kraton (4.3%) Mod. Conoco–Air Voids

Split Aggregates Case I–50 Blows



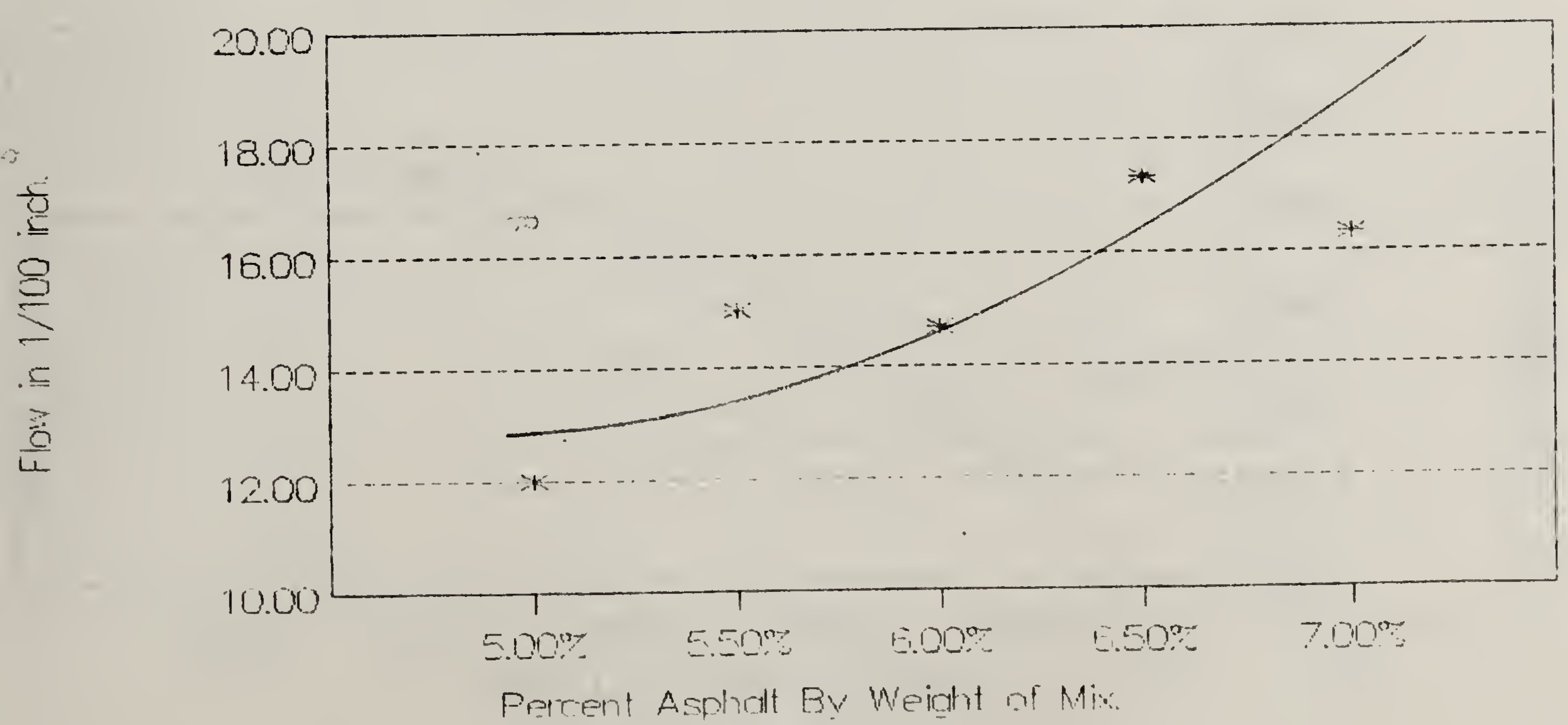
Polybilt Mod. Conoco—Stability

Split Aggregates Case I—50 Blows



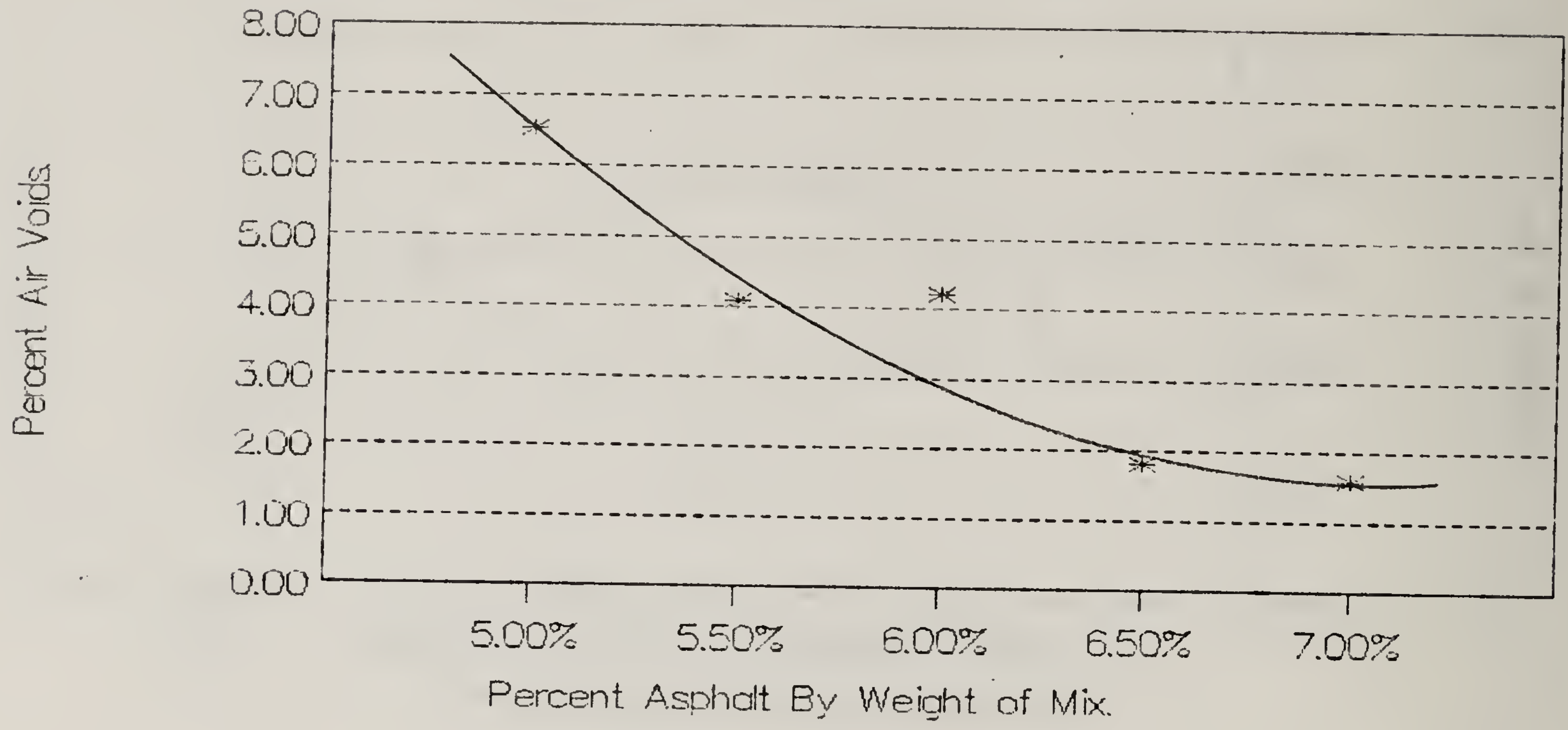
Polybilt Mod. Conoco—Flow

Split Aggregates Case I—50 Blows



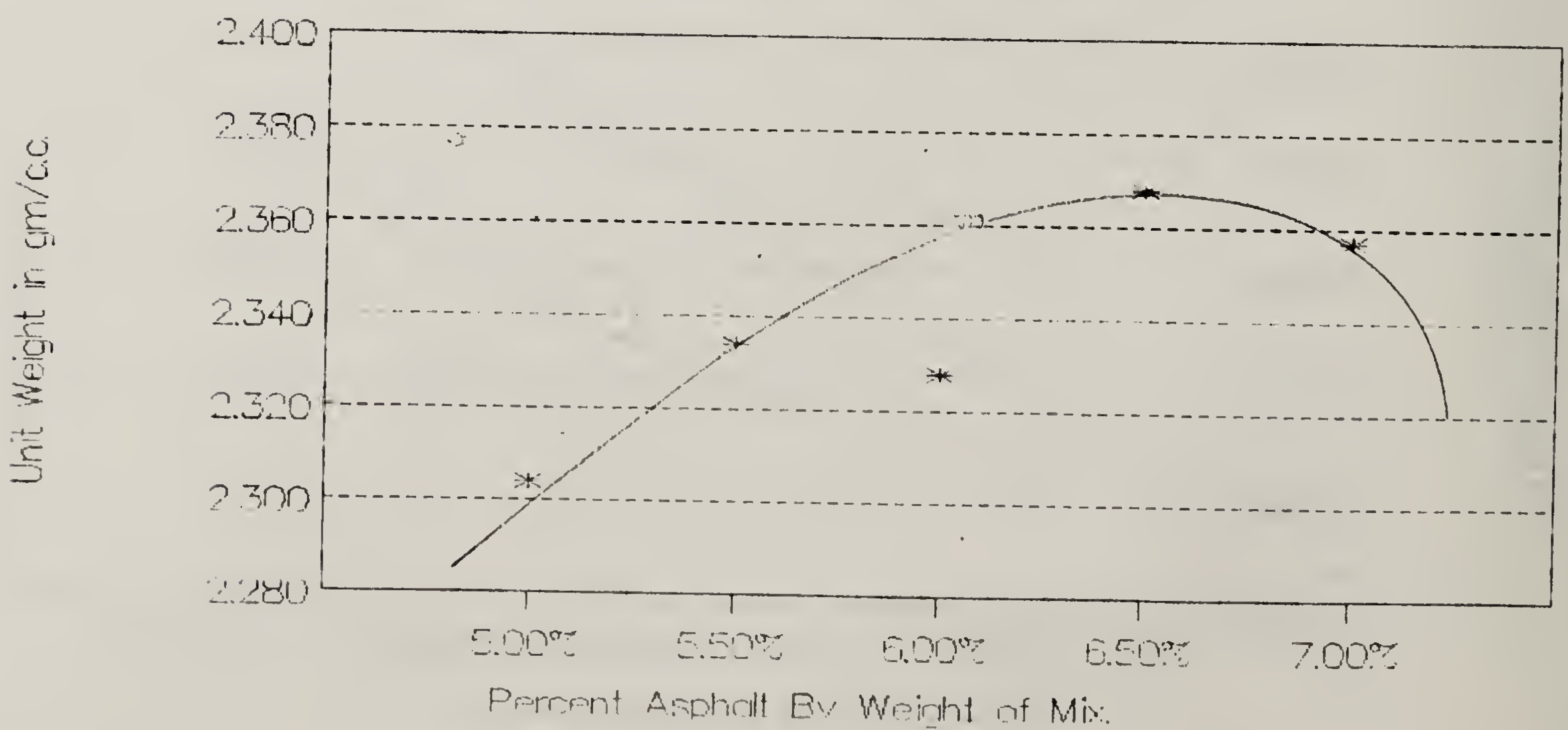
Polybilt Mod. Conoco–Air Voids

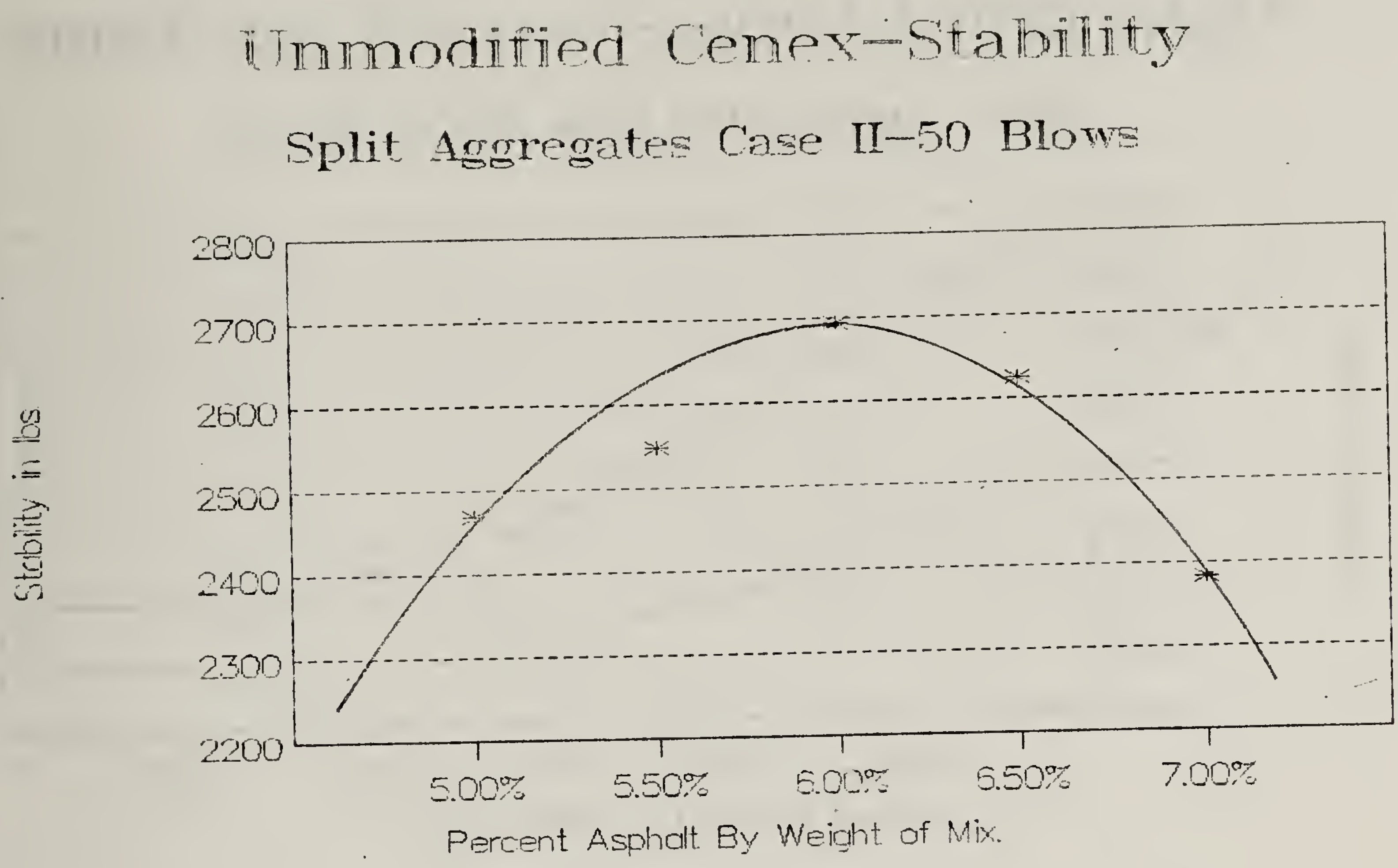
Split Aggregates Case I–50 Blows



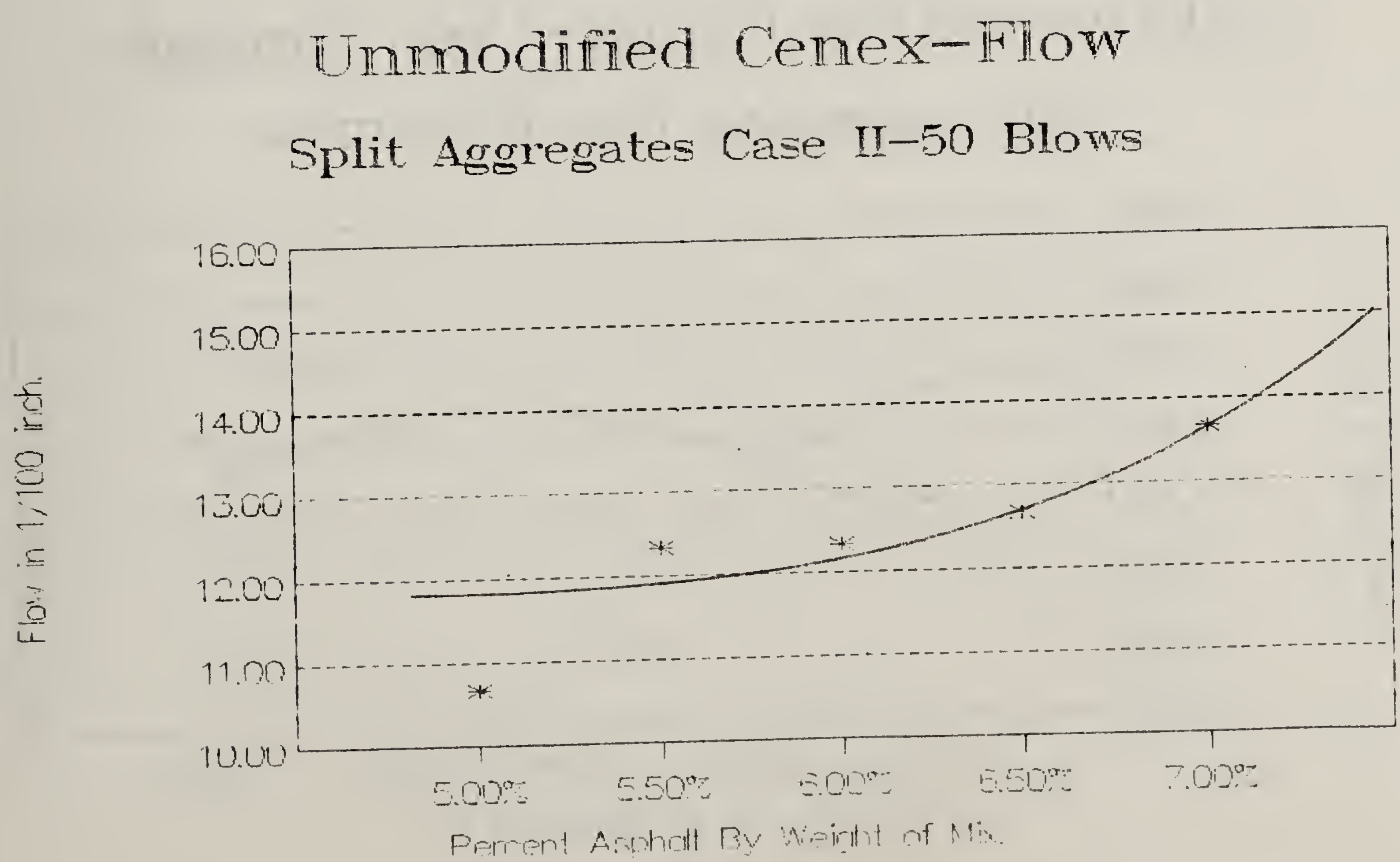
Polybilt Mod. Conoco–Unit Weight

Split Aggregates Case I–50 Blows





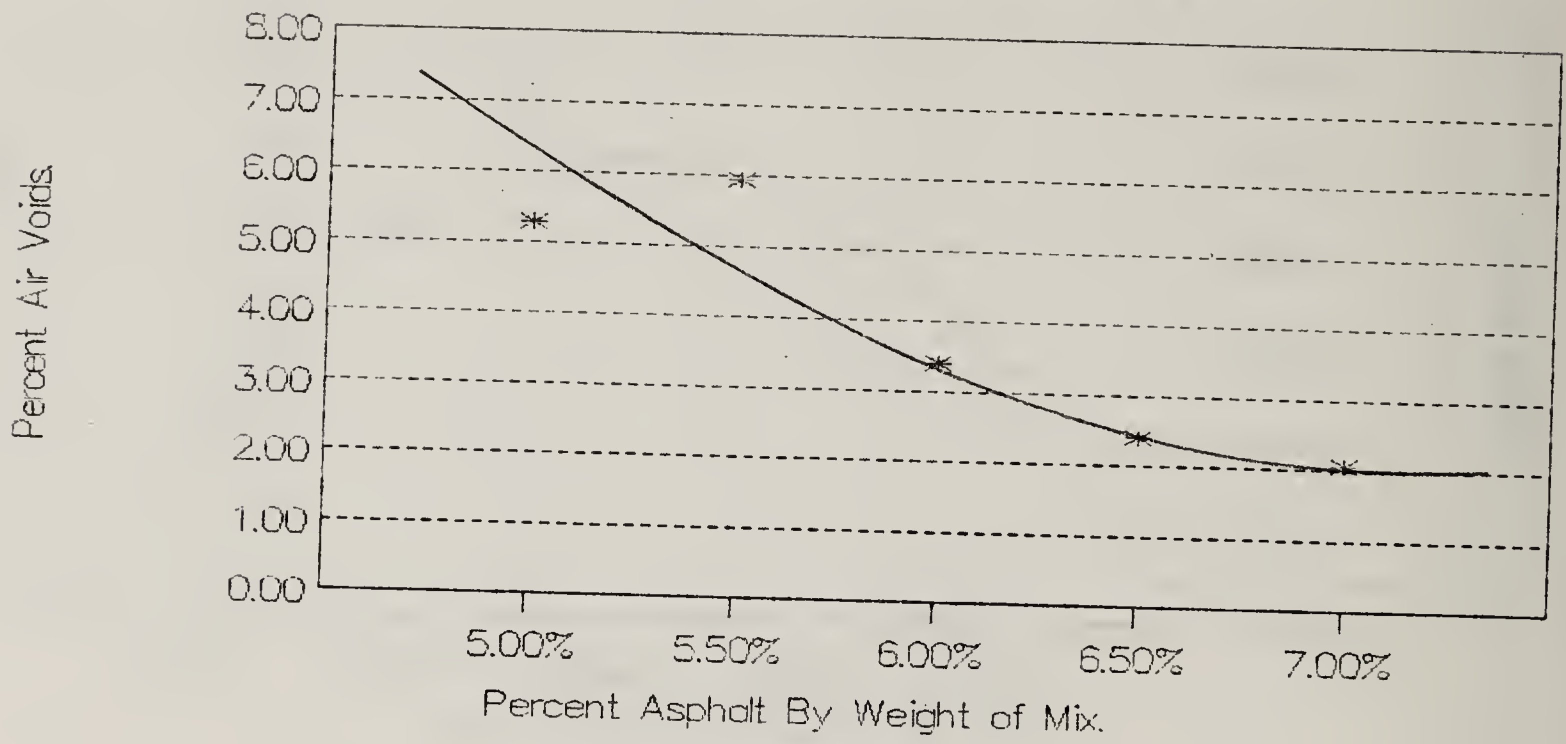
Unmodified Cenex–Stability
Split Aggregates Case II–50 Blows
2800
2700
2600
2500
2400
2300
2200
Stability in lbs
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.



Unmodified Cenex–Flow
Split Aggregates Case II–50 Blows
16.00
15.00
14.00
13.00
12.00
11.00
10.00
Flow in 1/100 inch.
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

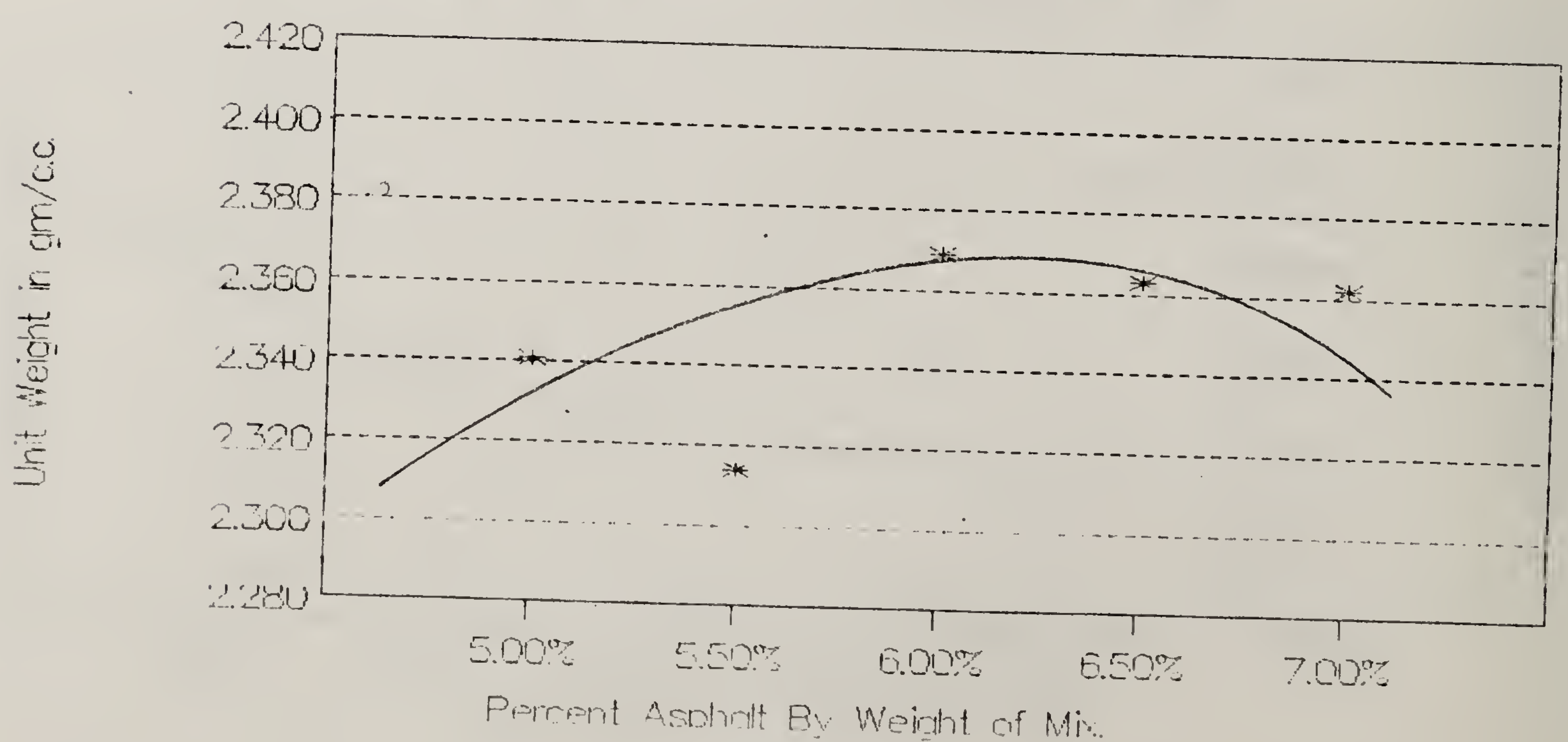
Unmodified Cenex–Percent Air Voids

Split Aggregates Case II–50 Blows



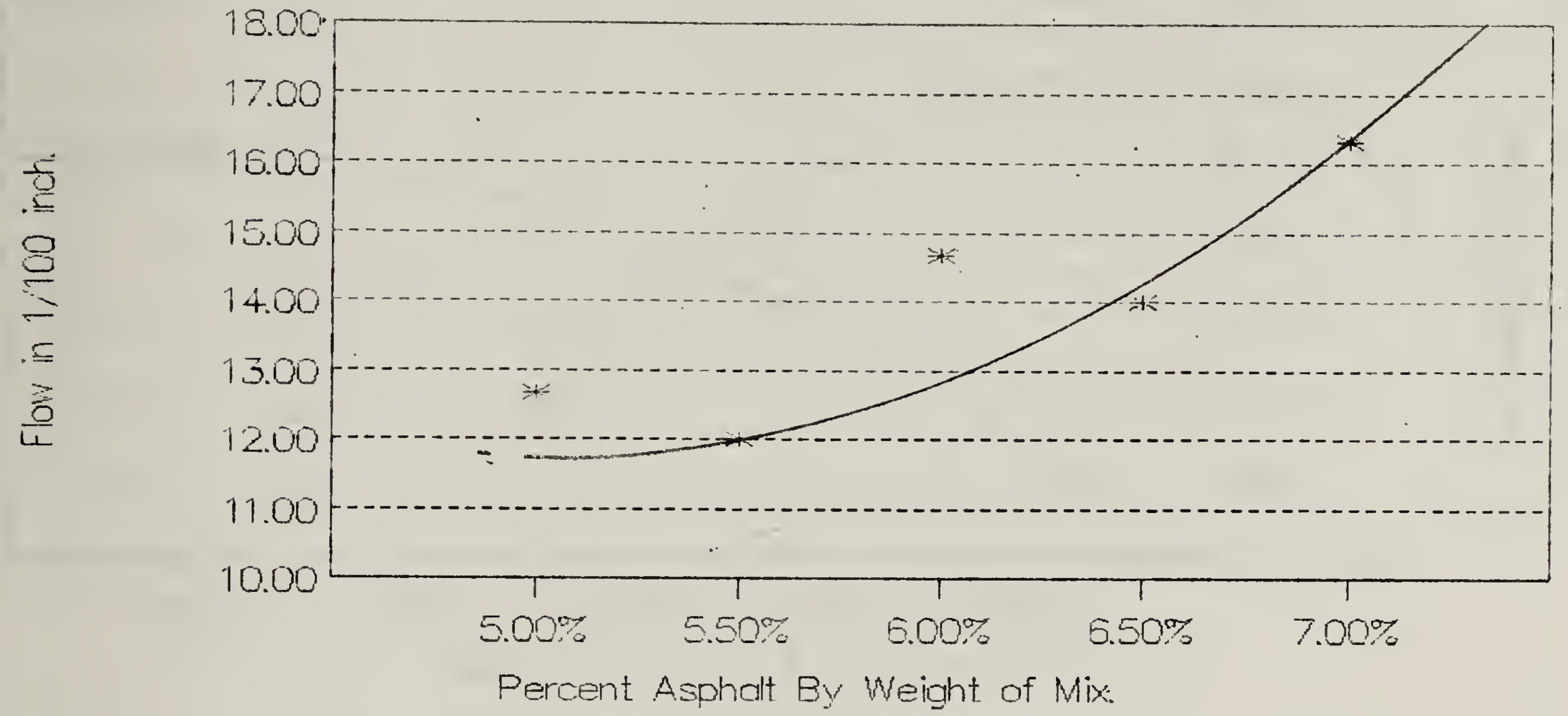
Unmodified Cenex–Unit Weight

Split Aggregates Case II–50 Blows



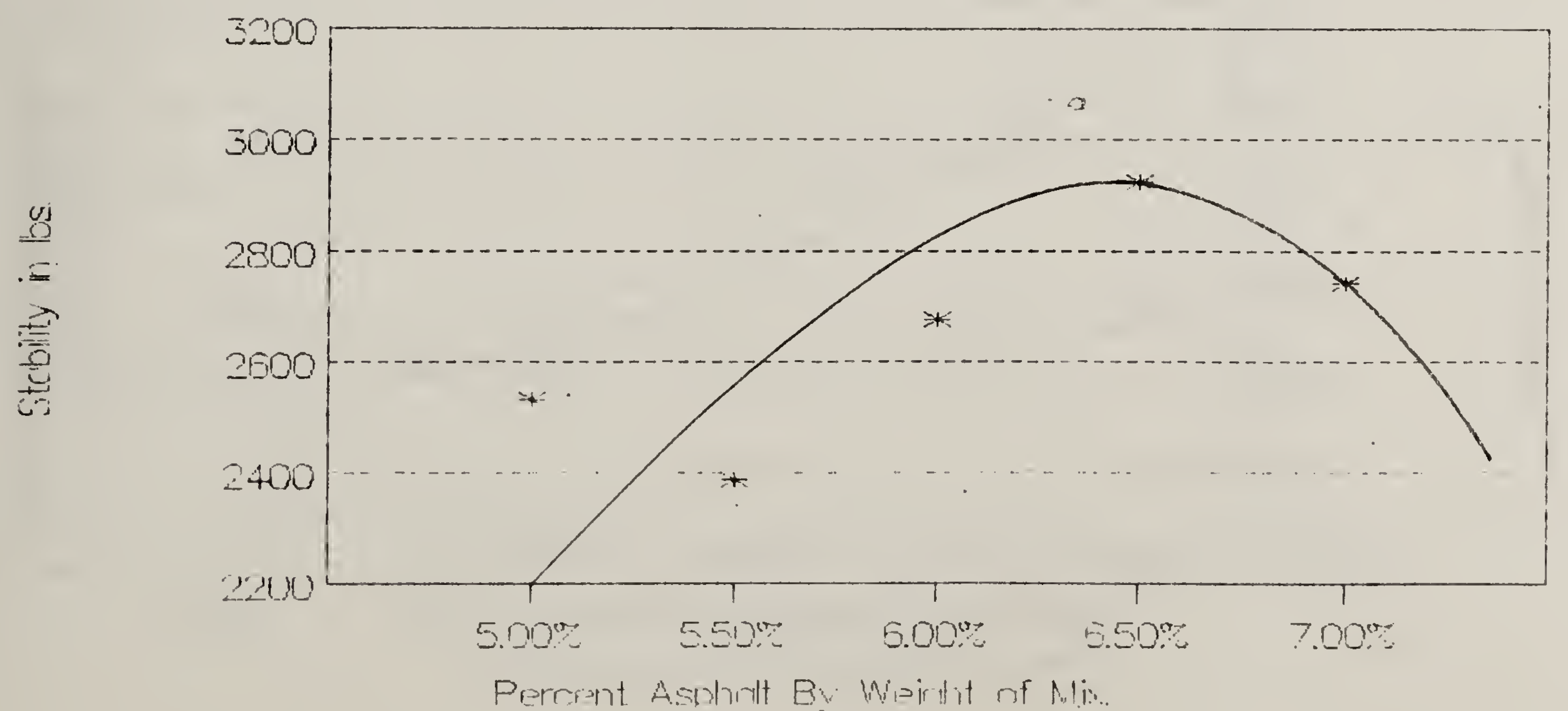
Kraton (4.3%) Mod. Cenex-Flow

Split Aggregates Case II-50 Blows



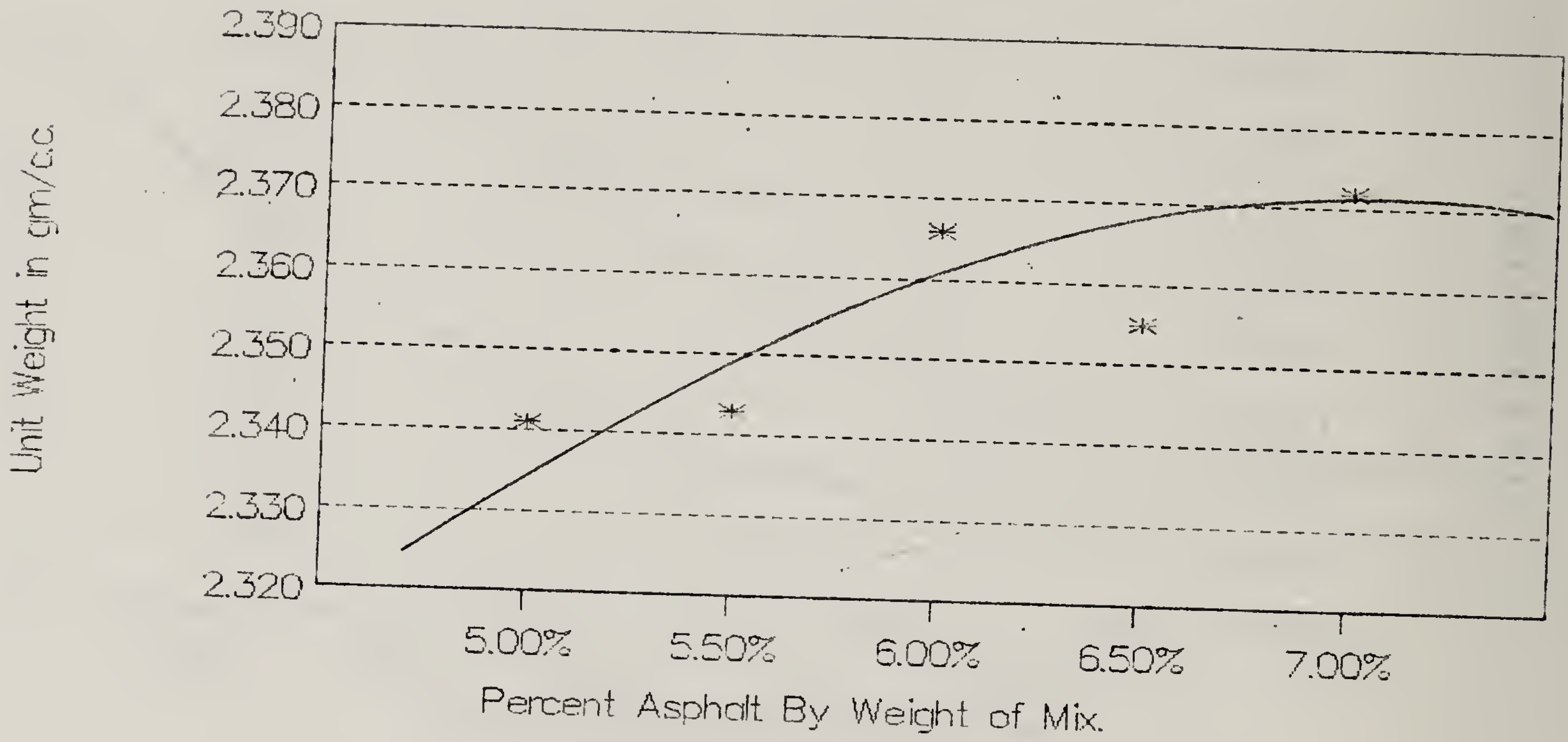
Kraton (4.3%) Mod. Cenex-Stability

Split Aggregates Case II-50 Blows



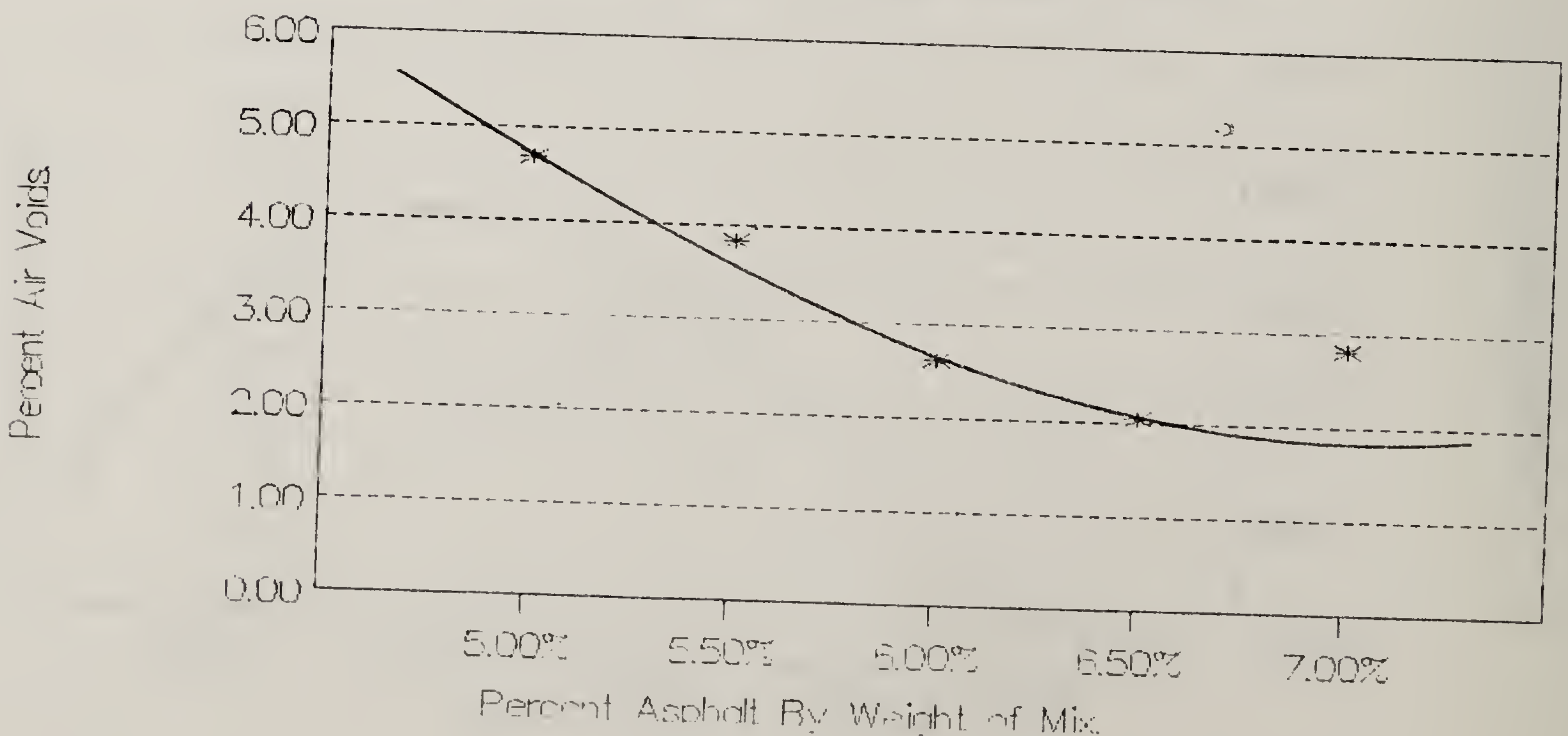
Kraton (4.3%) Mod. Cenex-Unit Weight

Split Aggregates Case II-50 Blows



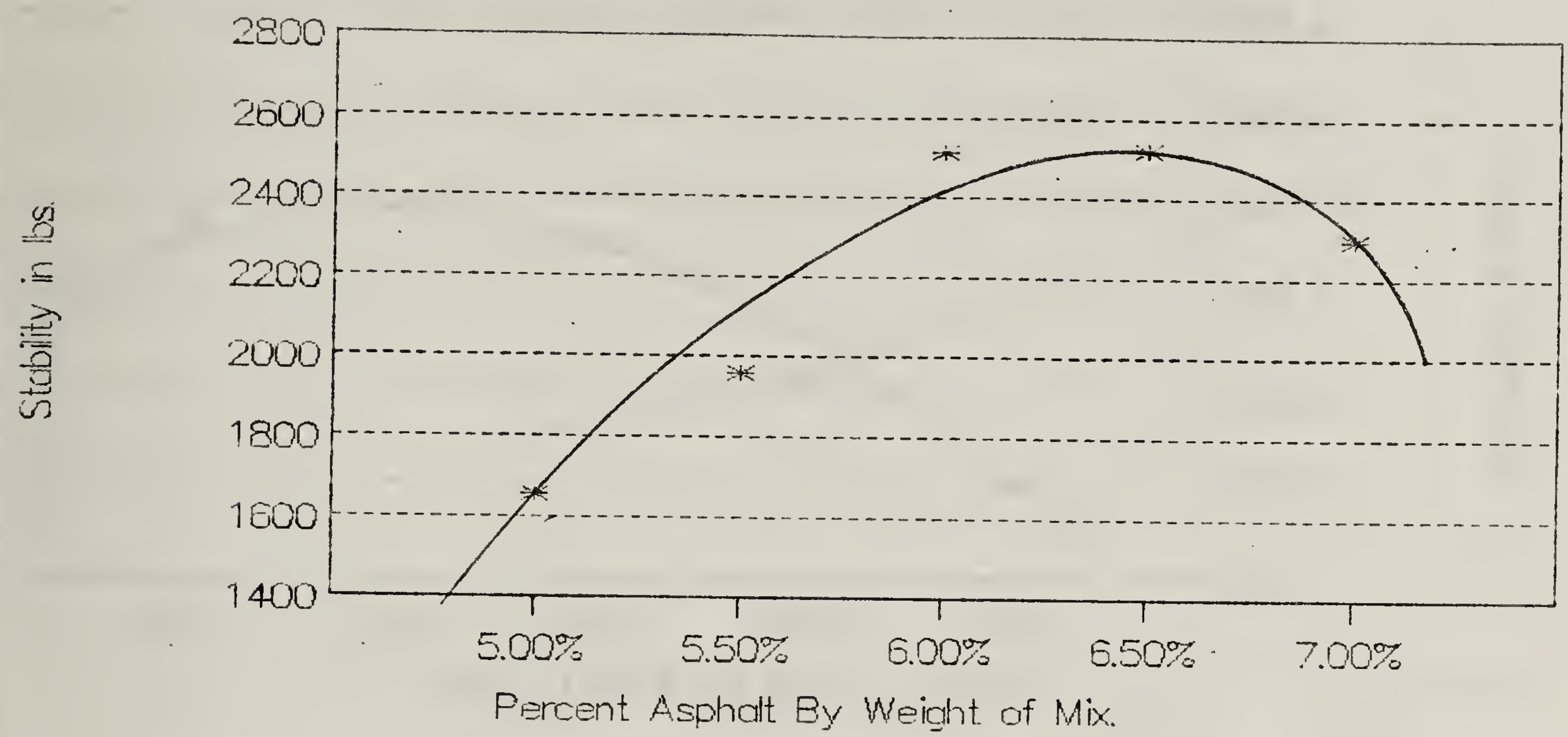
Kraton (4.3%) Mod. Cenex-Air Voids

Split Aggregates Case II-50 Blows



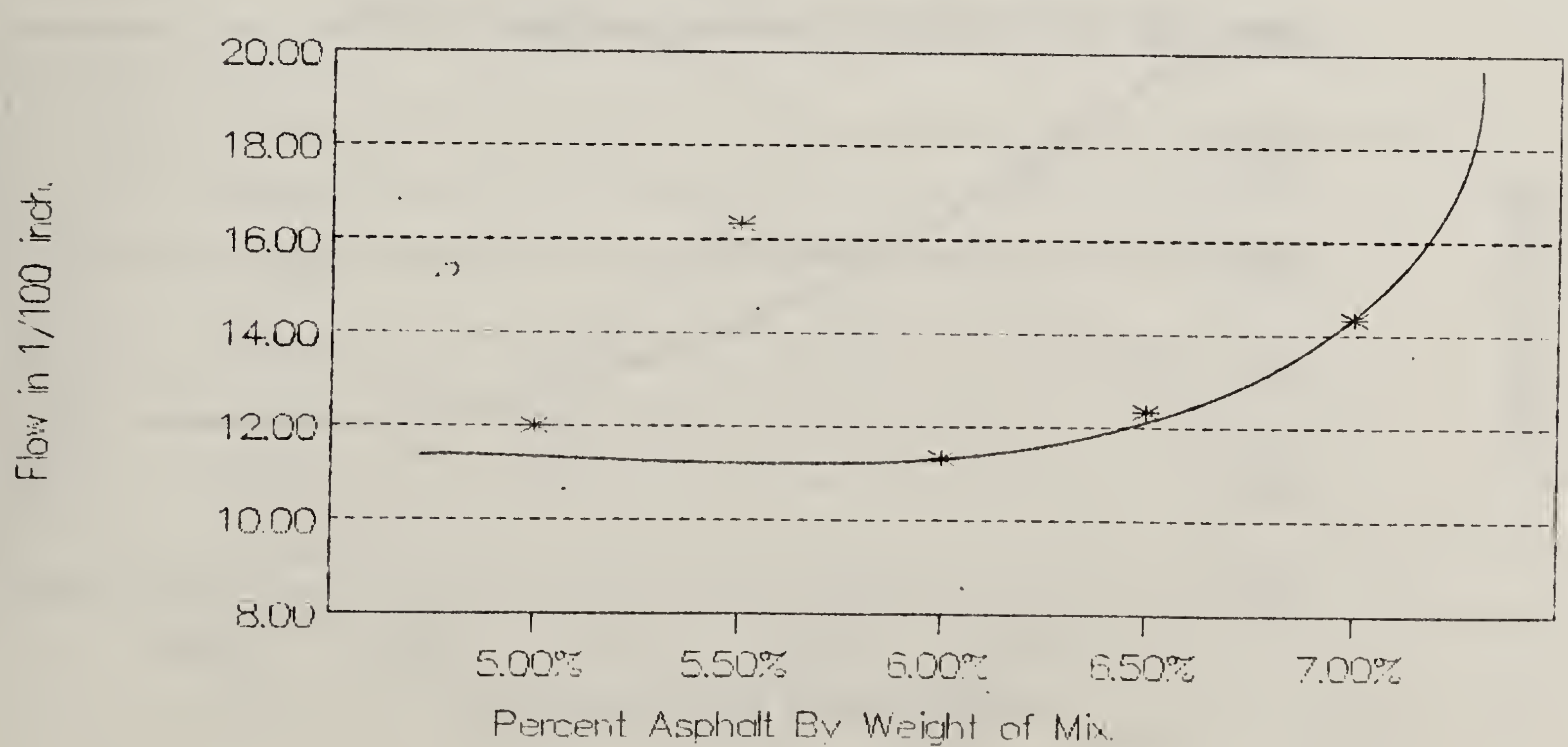
Kraton (6%) Mod. Cenex–Stability

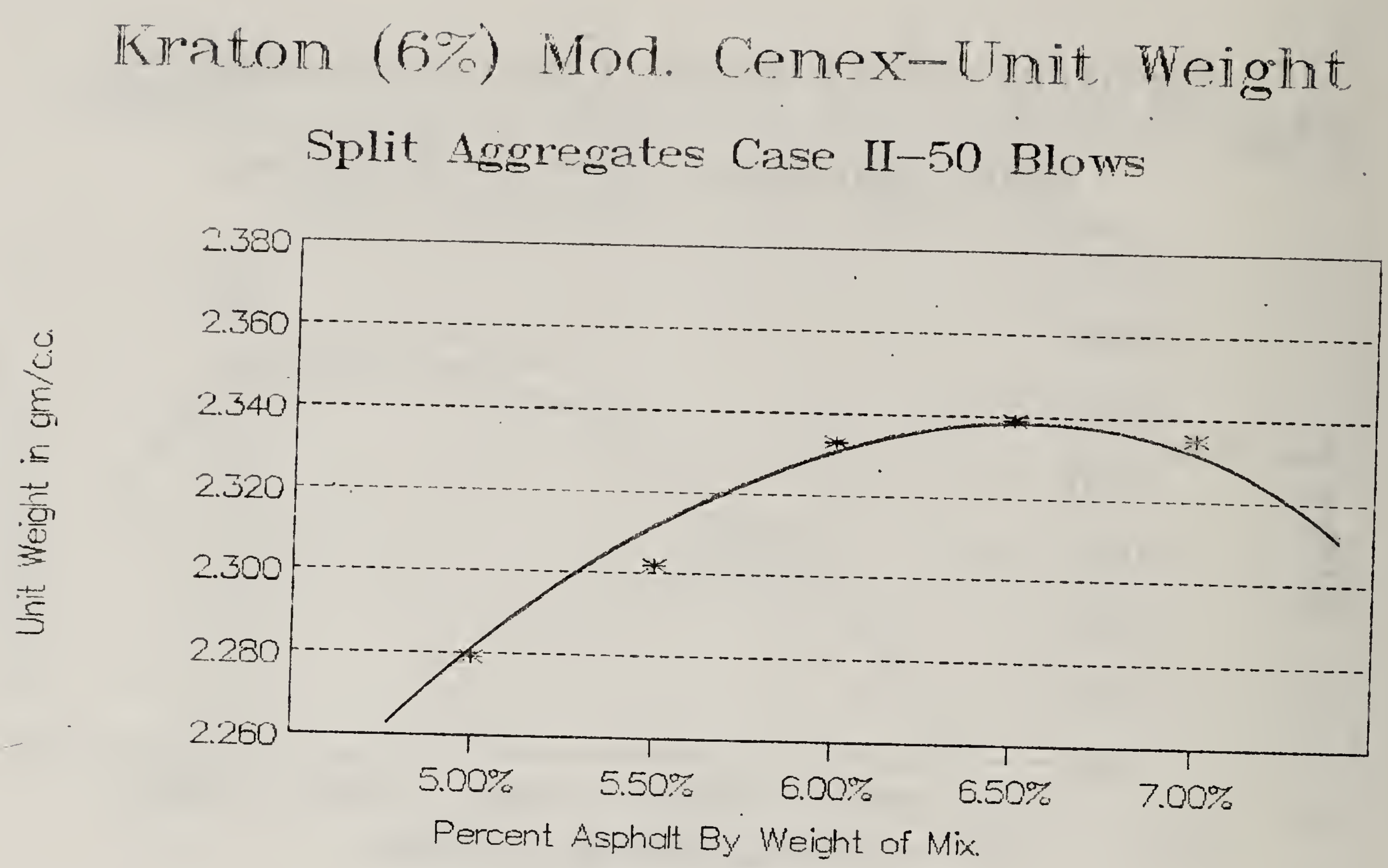
Split Aggregates Case II–50 Blows



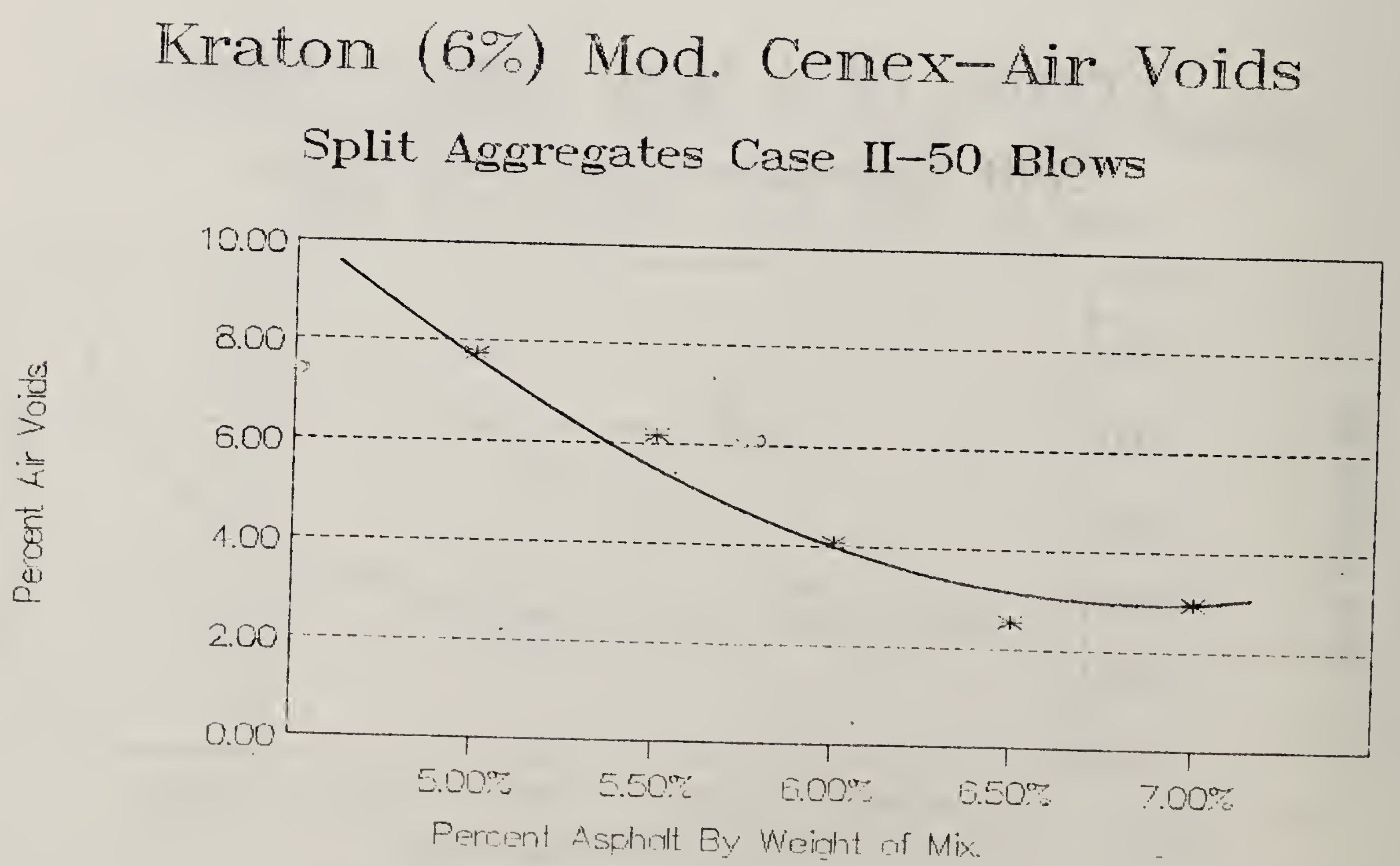
Kraton (6%) Mod. Cenex–Flow

Split Aggregates Case II–50 Blows





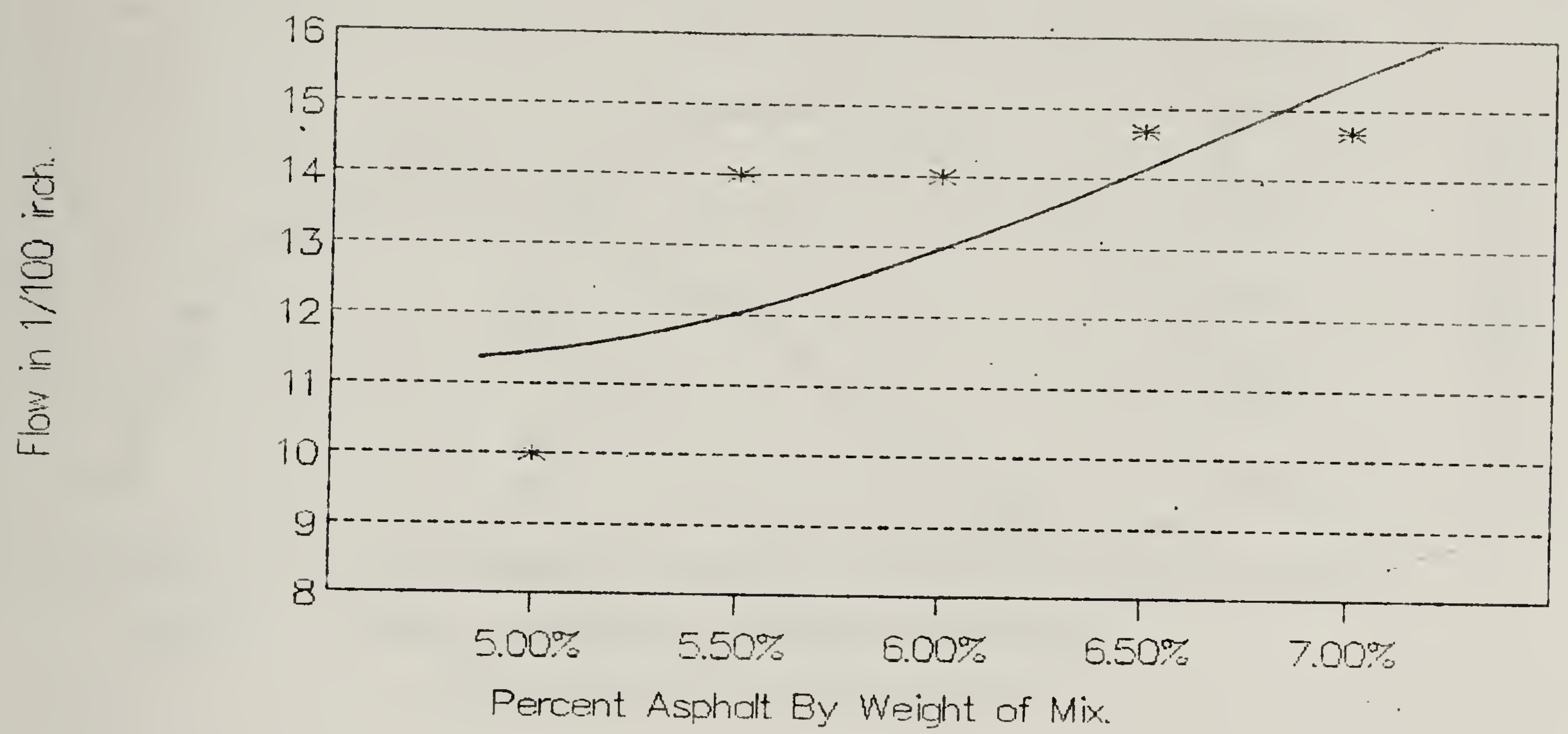
Kraton (6%) Mod. Cenex–Unit Weight
Split Aggregates Case II–50 Blows
Unit Weight in gm/c.c.
2.380
2.360
2.340
2.320
2.300
2.280
2.260
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.



Kraton (6%) Mod. Cenex–Air Voids
Split Aggregates Case II–50 Blows
Percent Air Voids
10.00
8.00
6.00
4.00
2.00
0.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

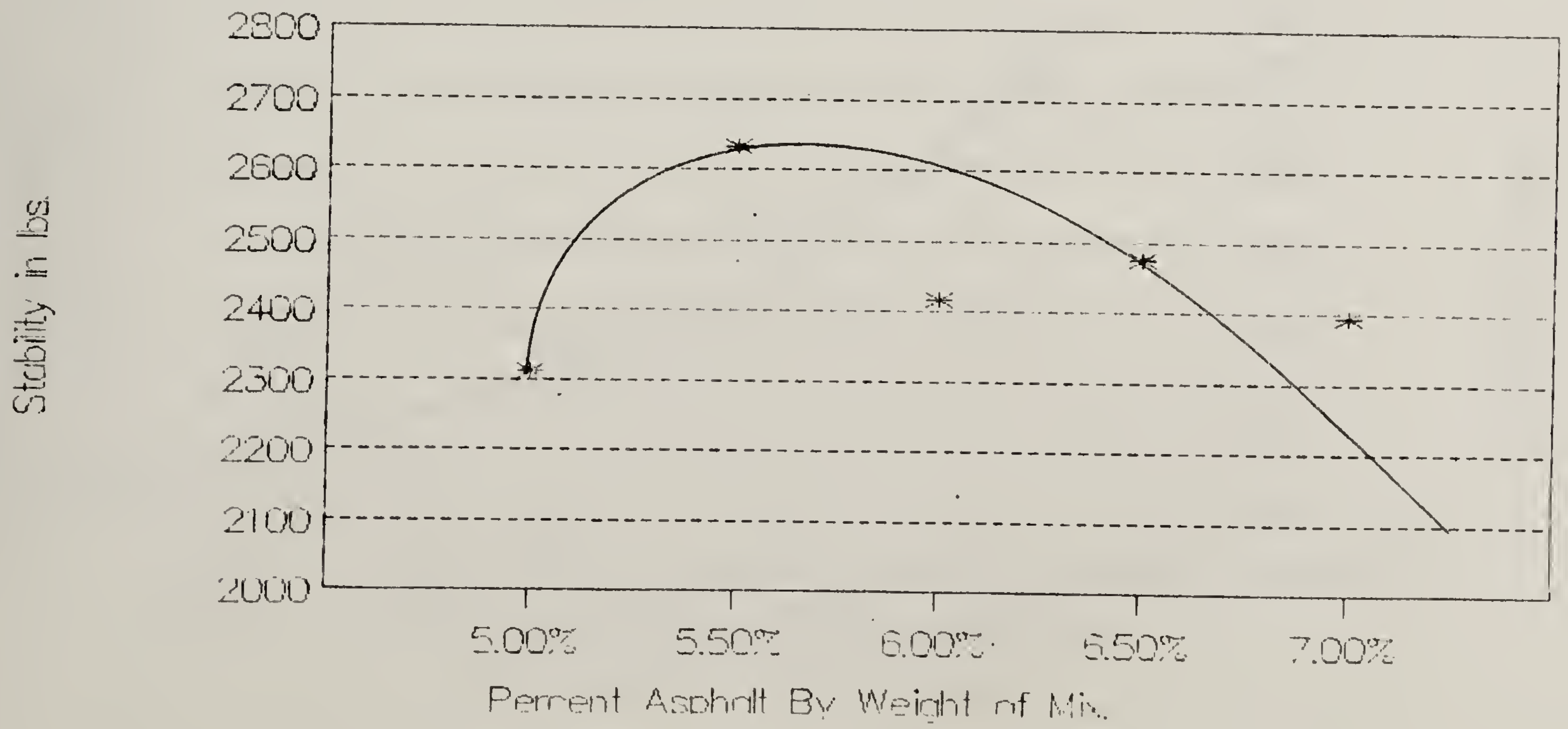
Polybilt Mod. Cenex–Flow

Split Aggregates Case II–50 Blows



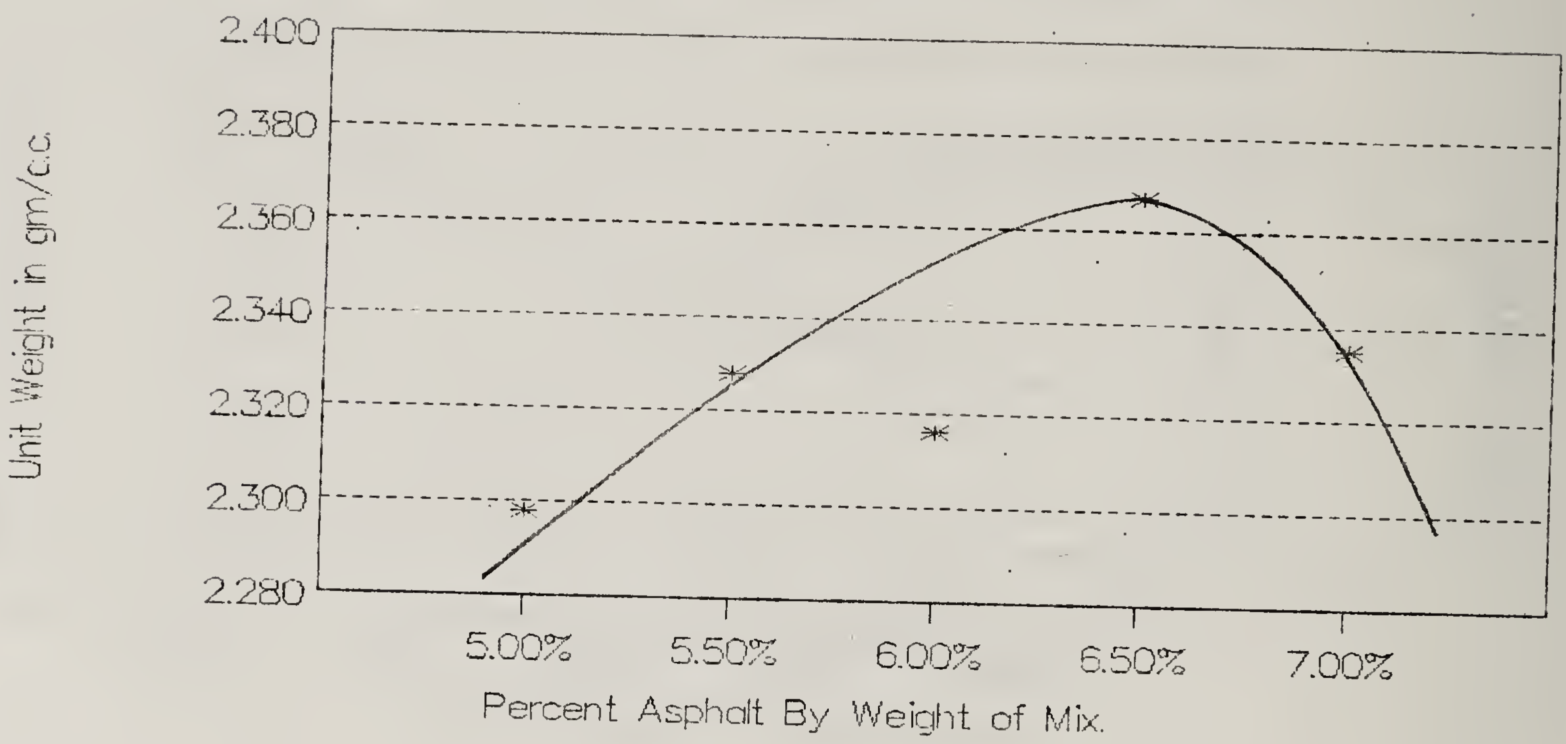
Polybilt Mod. Cenex–Stability

Split Aggregates Case II–50 Blows



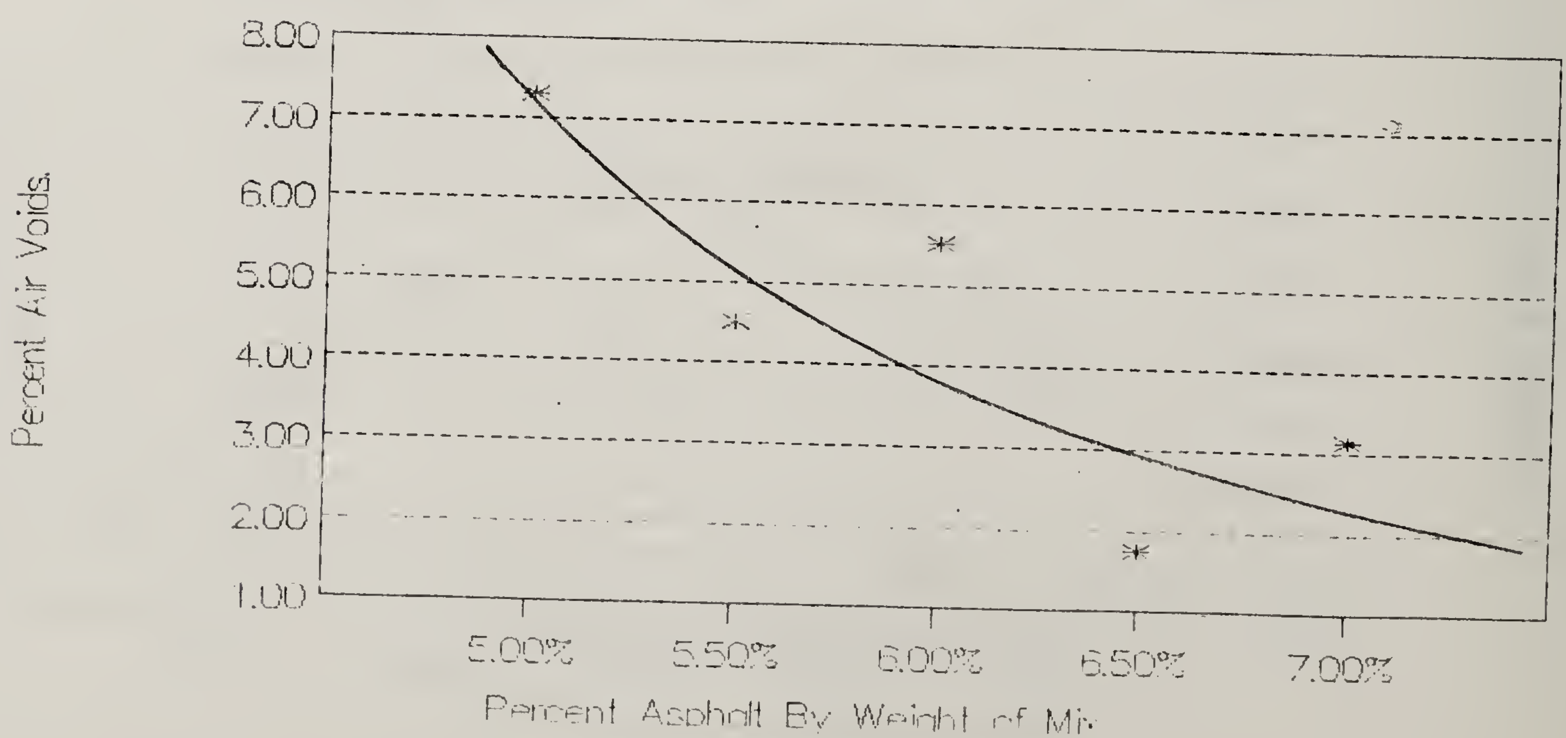
Polybilt Mod. Cenex–Unit Weight

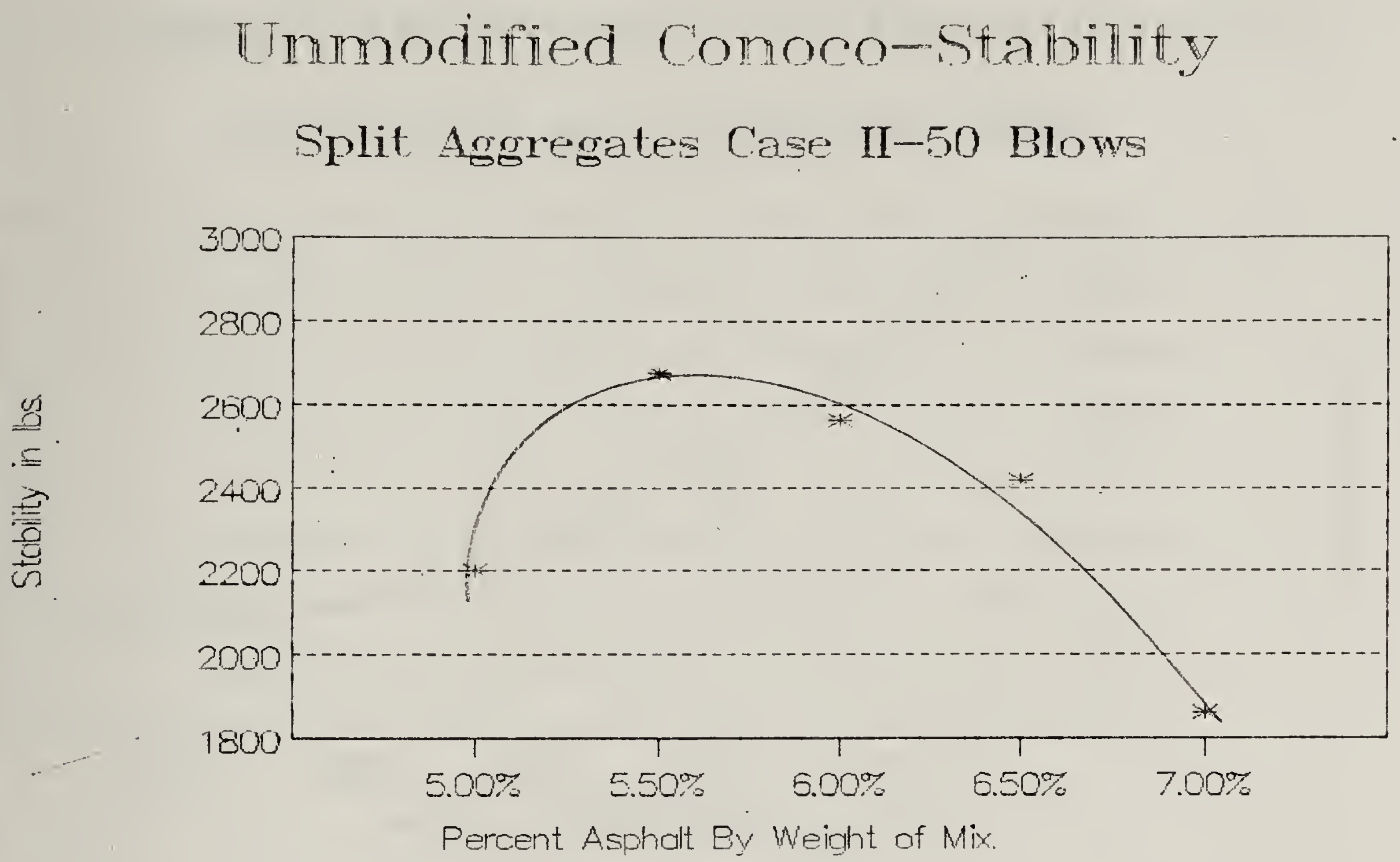
Split Aggregates Case II–50 Blows



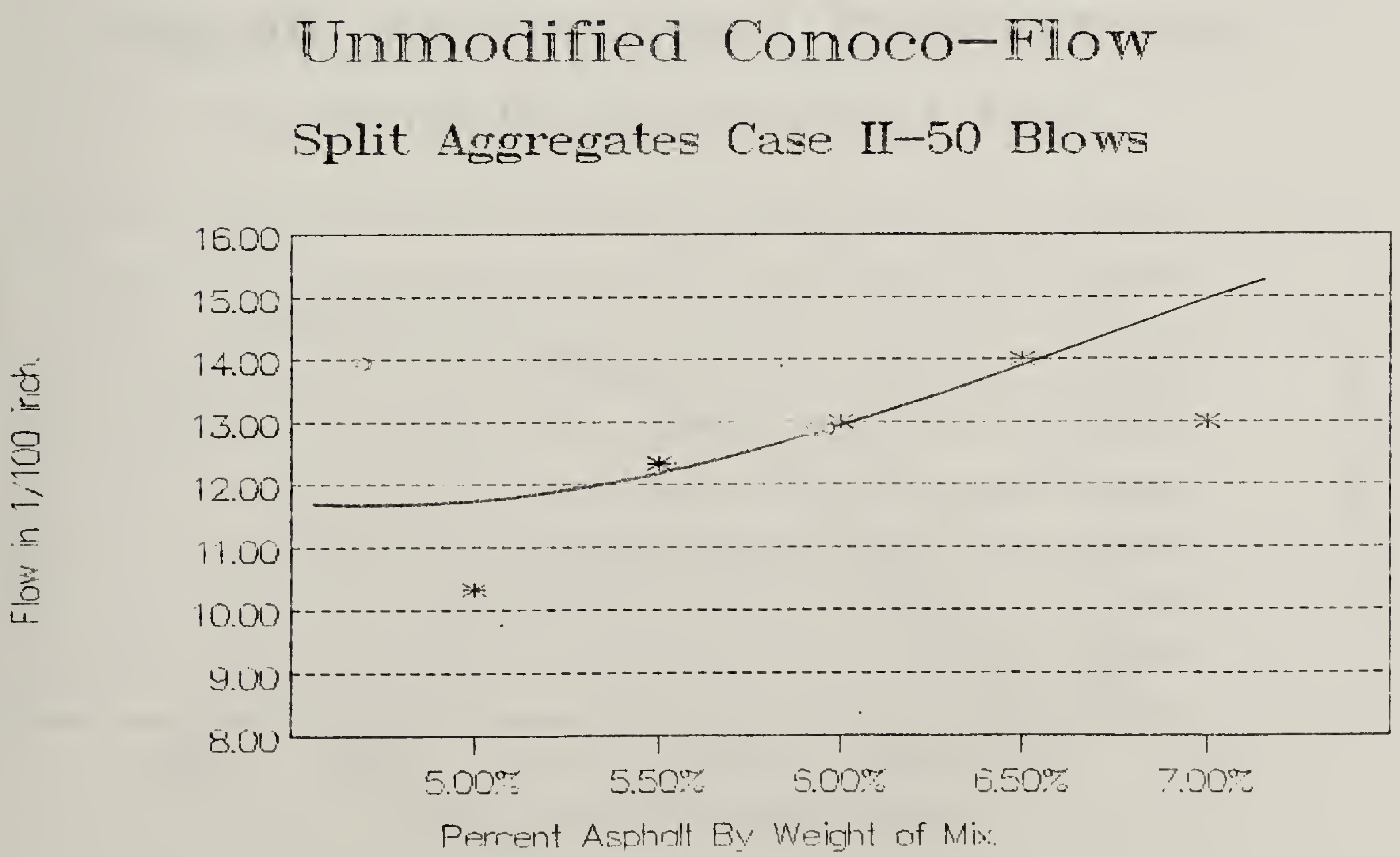
Polybilt Mod. Cenex–Percent Air Voids

Split Aggregates Case II–50 Blows

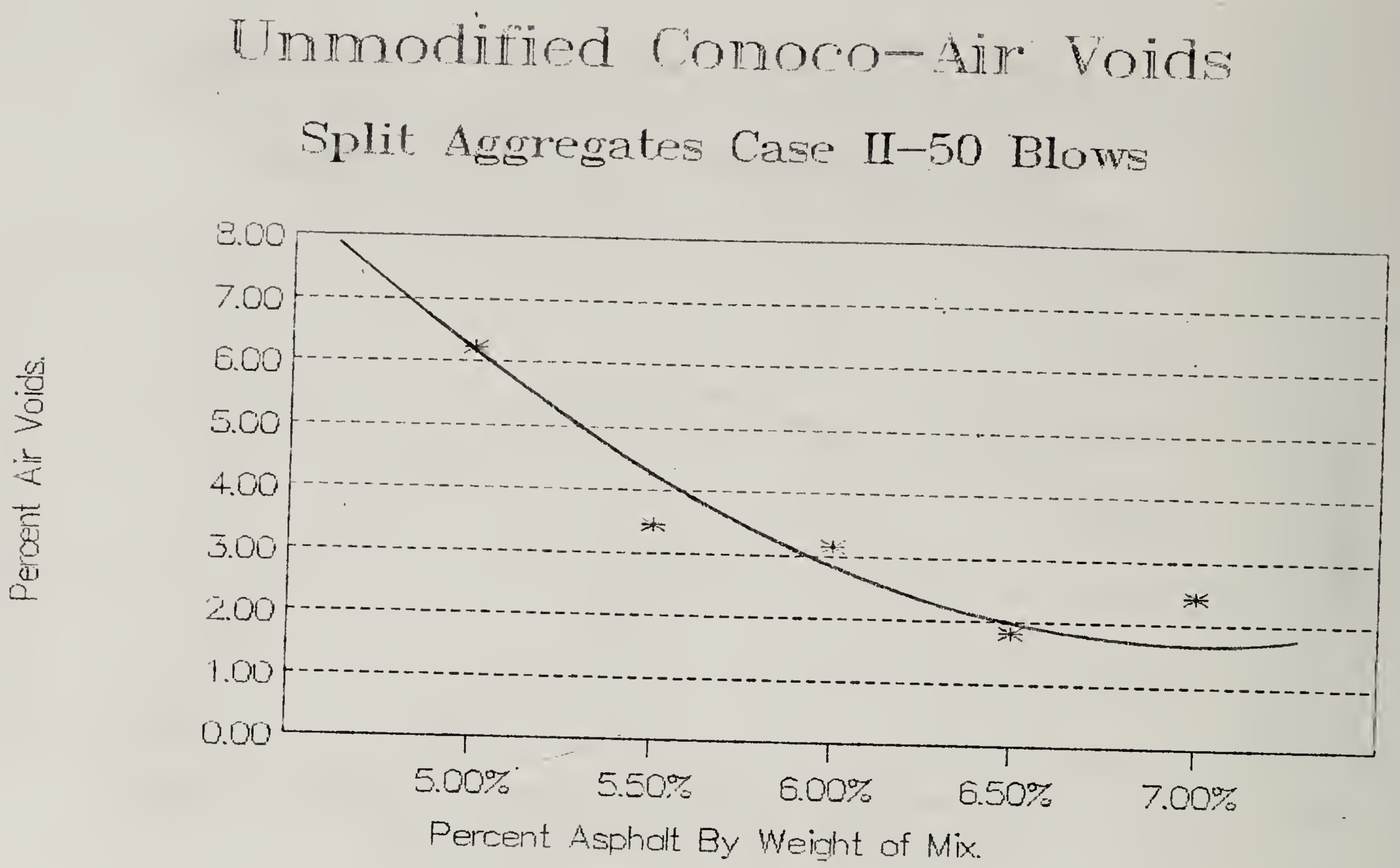


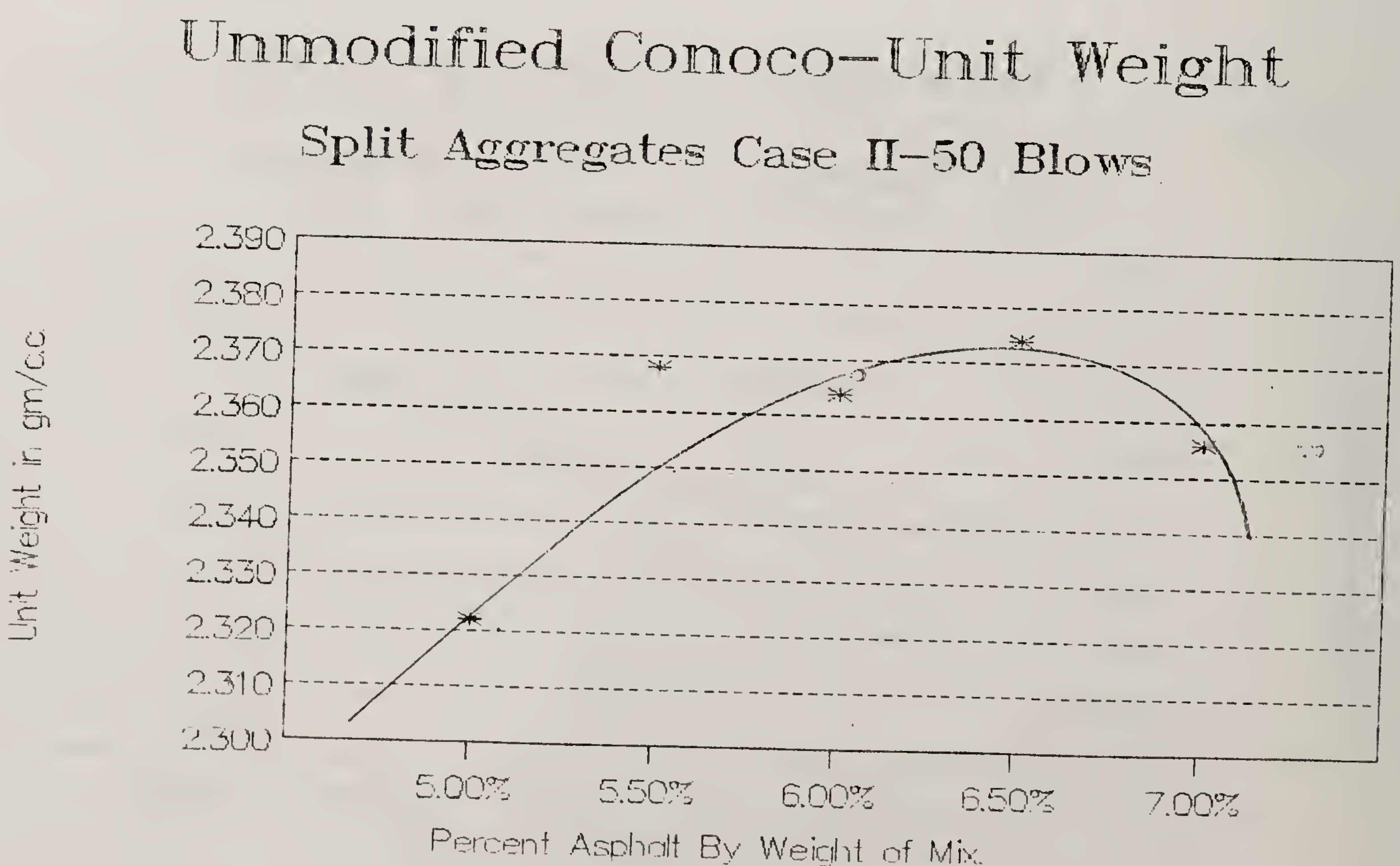


Unmodified Conoco-Stability
Split Aggregates Case II-50 Blows
3000
2800
2600
2400
2200
2000
1800
Stability in lbs.
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.



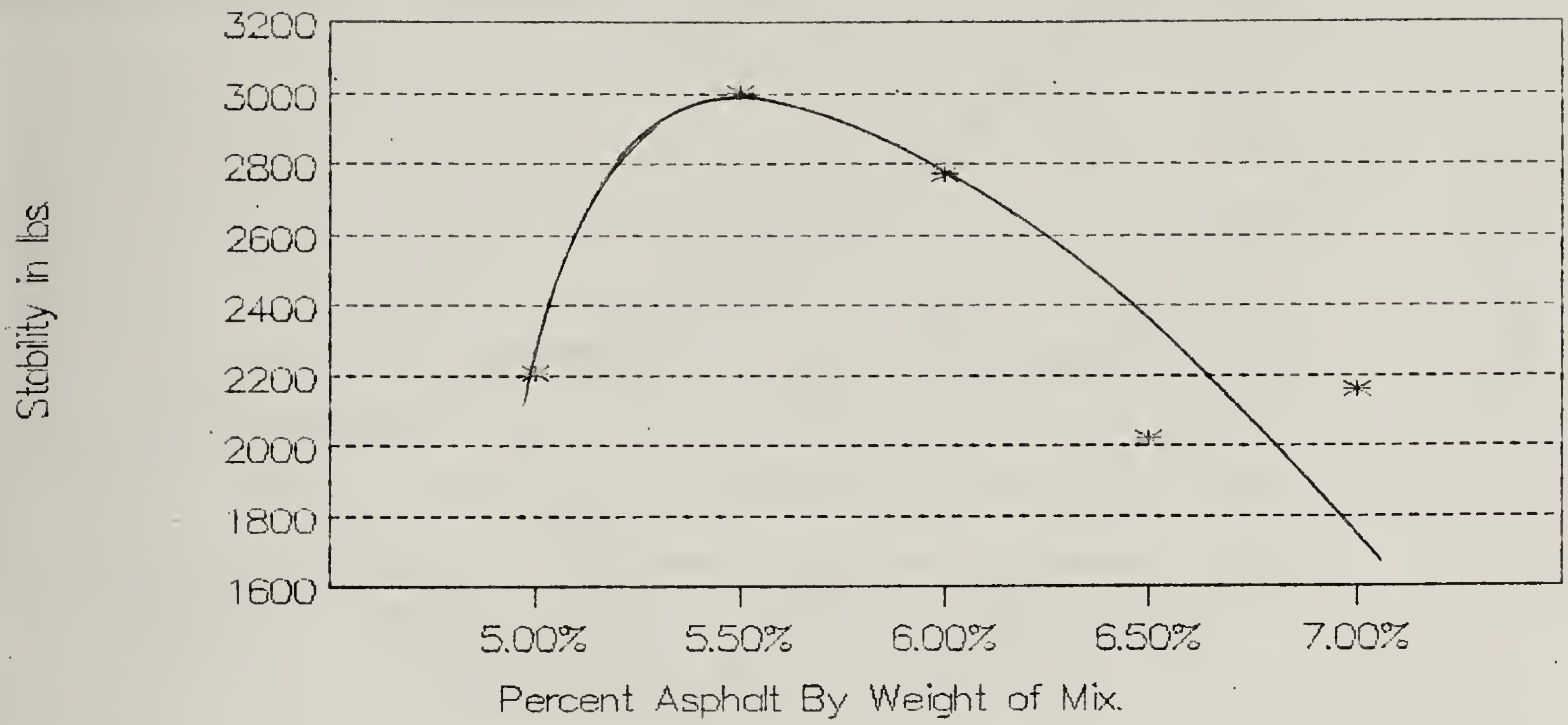
Unmodified Conoco-Flow
Split Aggregates Case II-50 Blows
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
Flow in 1/100 inch.
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Unmodified Conoco-Air Voids
Split Aggregates Case II-50 Blows
Percent Air Voids
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Unmodified Conoco-Unit Weight
Split Aggregates Case II-50 Blows
Unit Weight in gm/c.c.
2.390
2.380
2.370
2.360
2.350
2.340
2.330
2.320
2.310
2.300
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

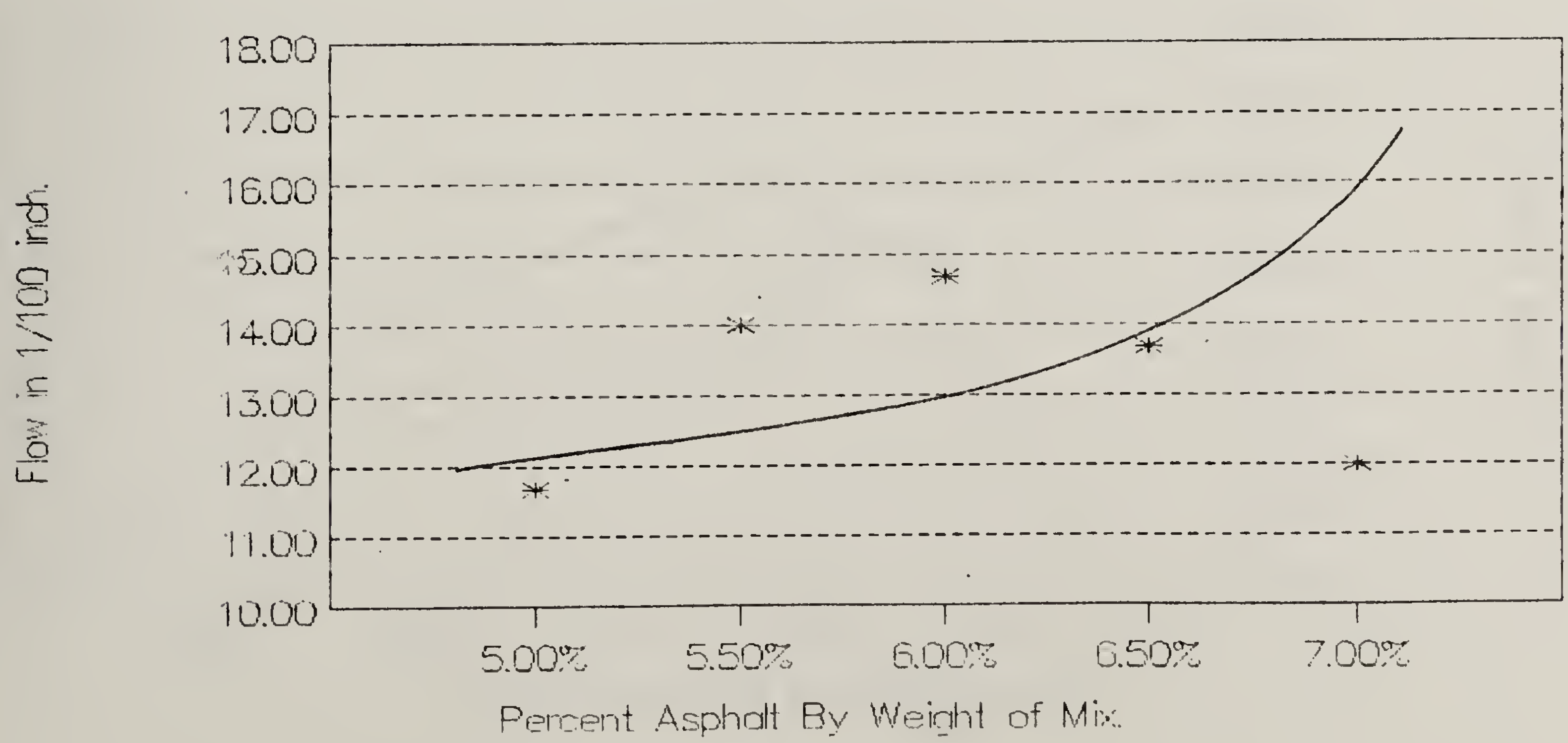
Kraton (4.3%) Mod. Conoco–Stability

Split Aggregates Case II–50 Blows



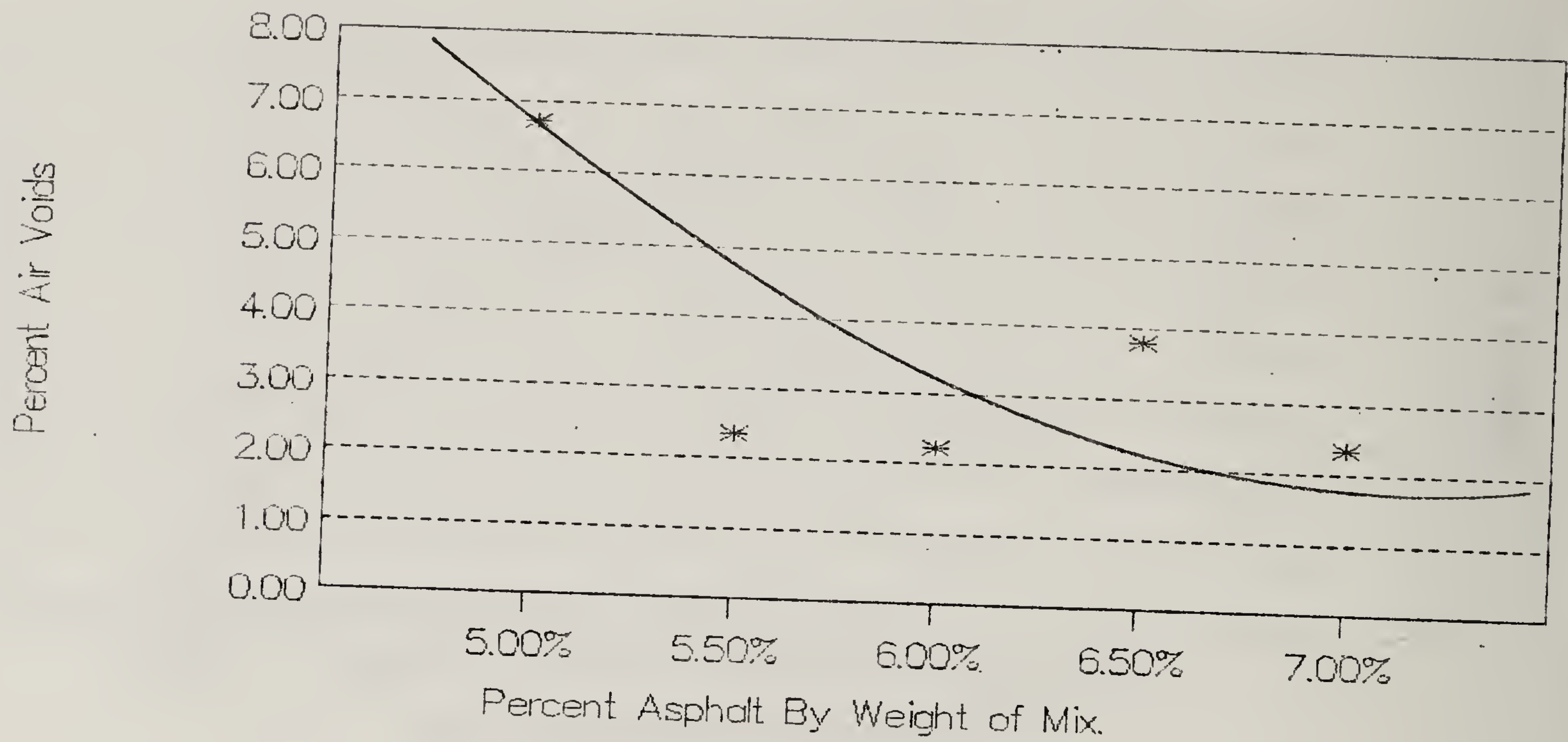
Kraton (4.3%) Mod. Conoco–Flow

Split Aggregates Case II–50 Blows



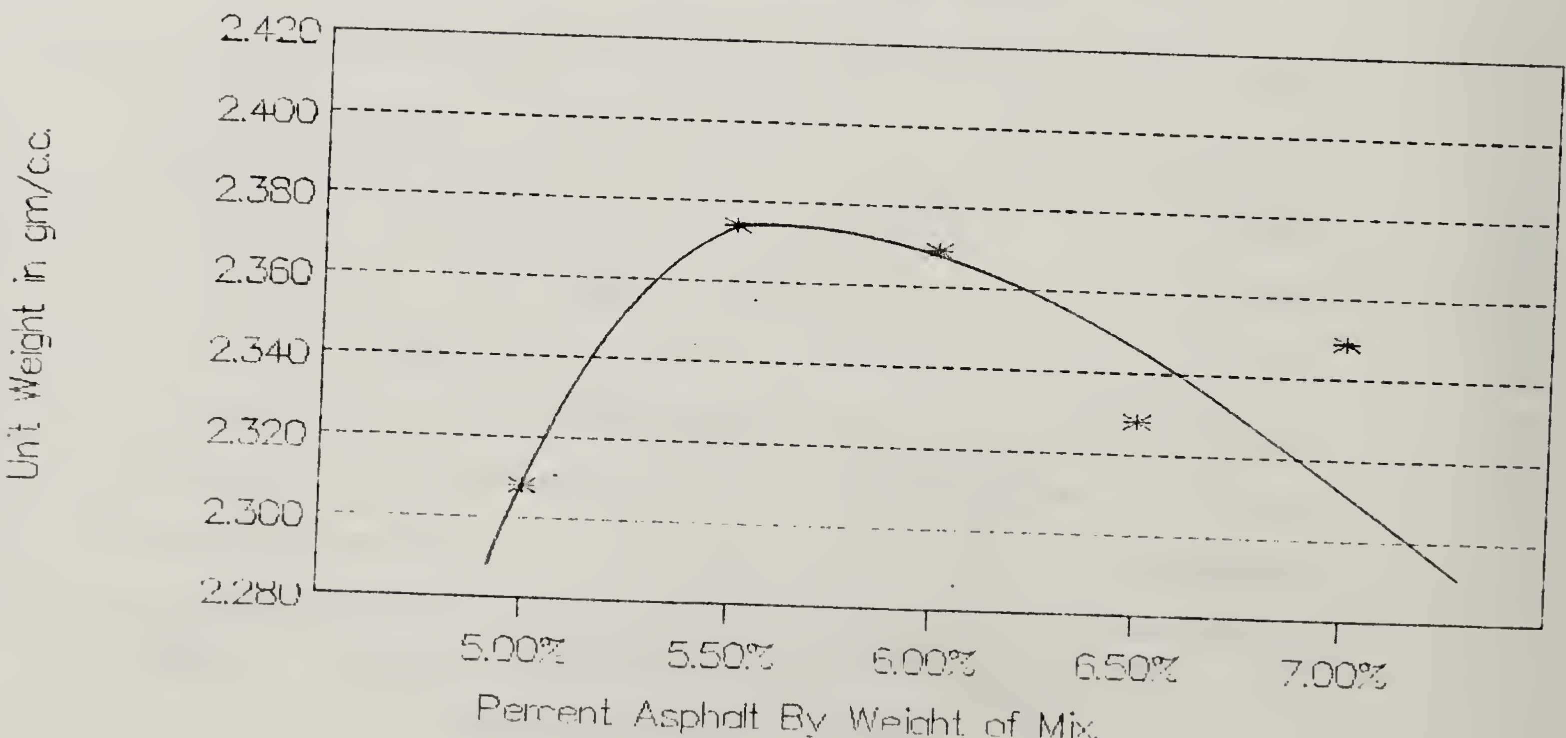
Kraton (4.3%) Mod. Conoco-Air Voids

Split Aggregates Case II-50 Blows



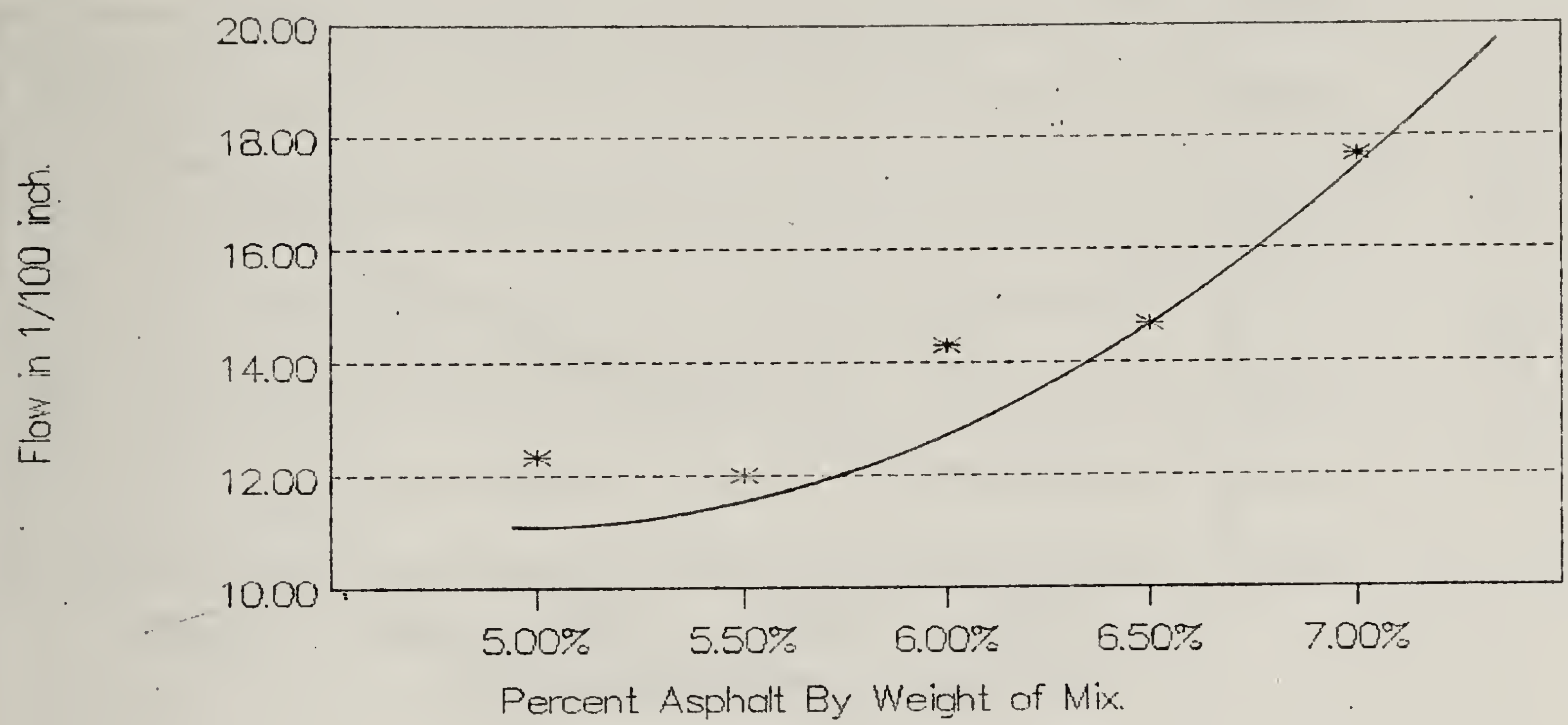
Kraton (4.3%) Mod. Conoco-Unit Weight

Split Aggregates Case II-50 Blows



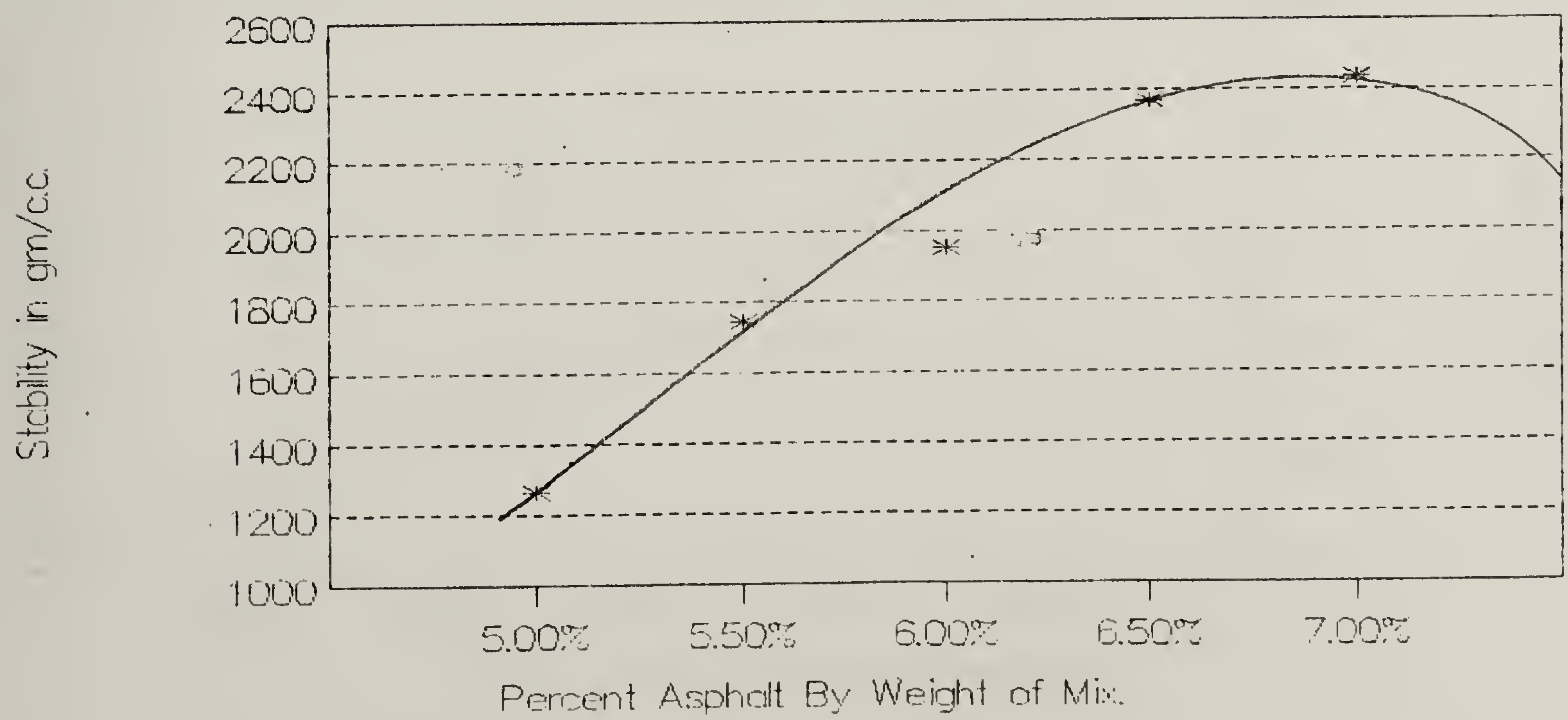
Kraton (6%) Mod. Conoco–Flow

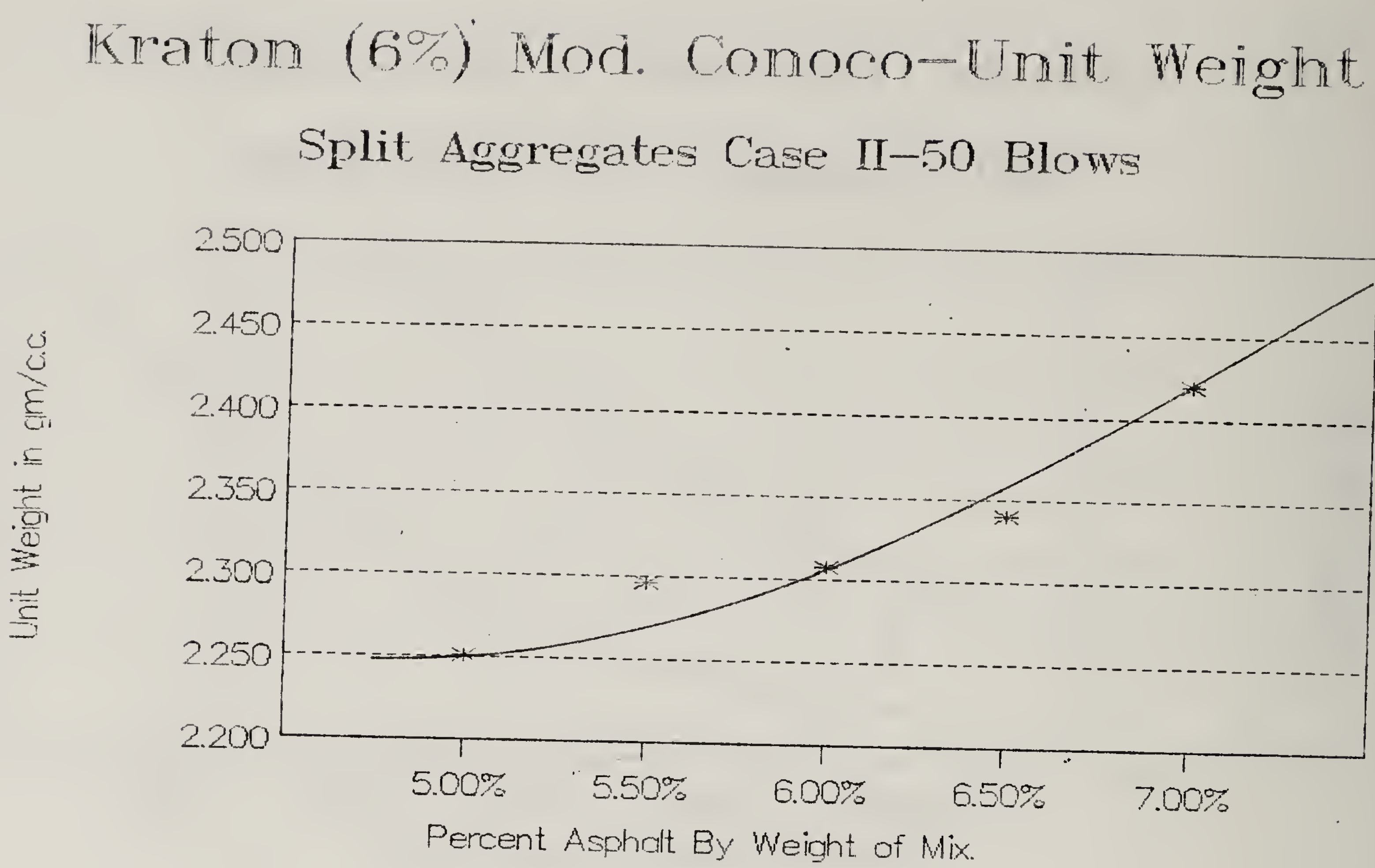
Split Aggregates Case II–50 Blows

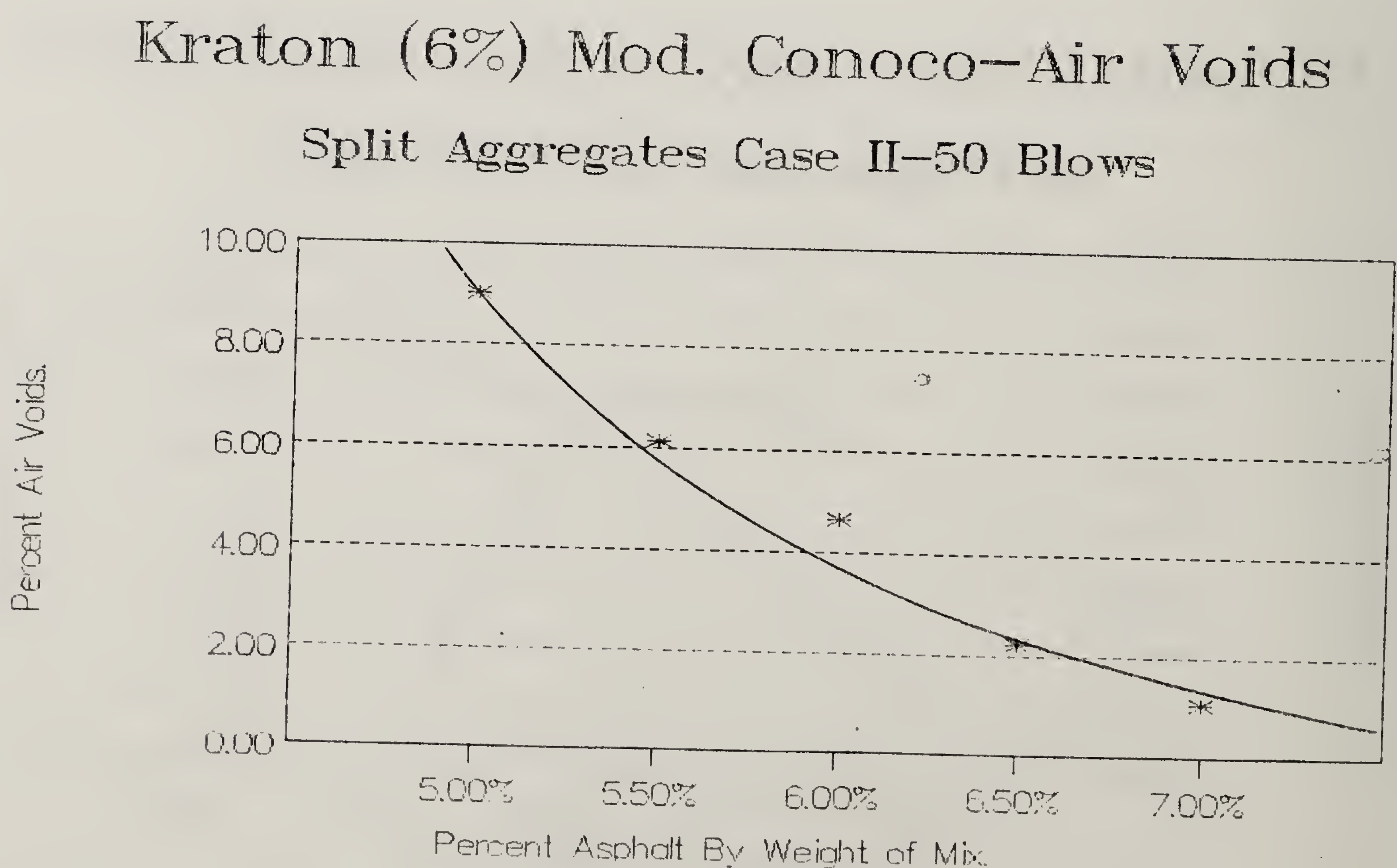


Kraton (6%) Mod. Conoco–Stability

Split Aggregates Case II–50 Blows

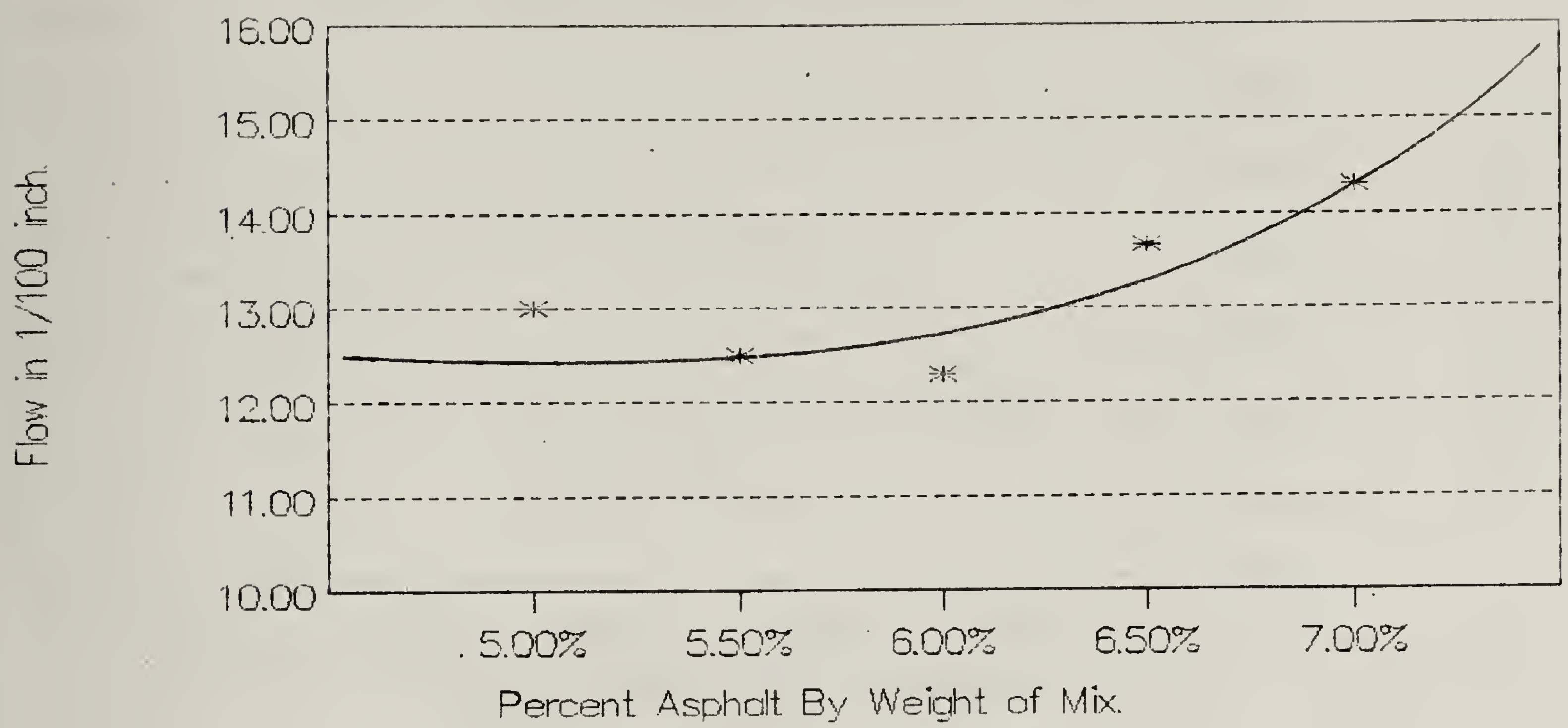



Kraton (6%) Mod. Conoco-Unit Weight
Split Aggregates Case II-50 Blows
Unit Weight in gm/c.c.
2.500
2.450
2.400
2.350
2.300
2.250
2.200
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Kraton (6%) Mod. Conoco-Air Voids
Split Aggregates Case II-50 Blows
Percent Air Voids.
10.00
8.00
6.00
4.00
2.00
0.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

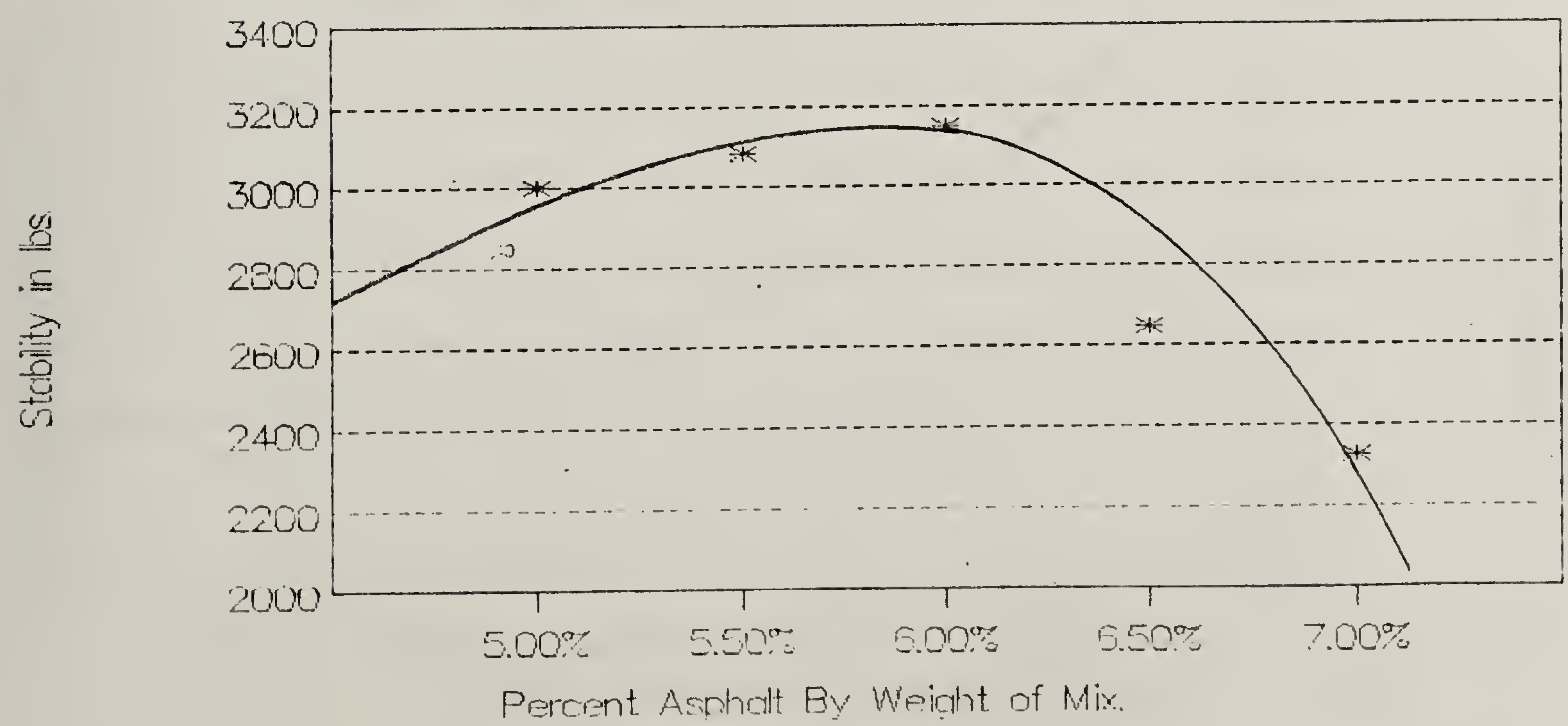
Polybilt Mod. Conoco–Flow

Split Aggregates Case II–50 Blows



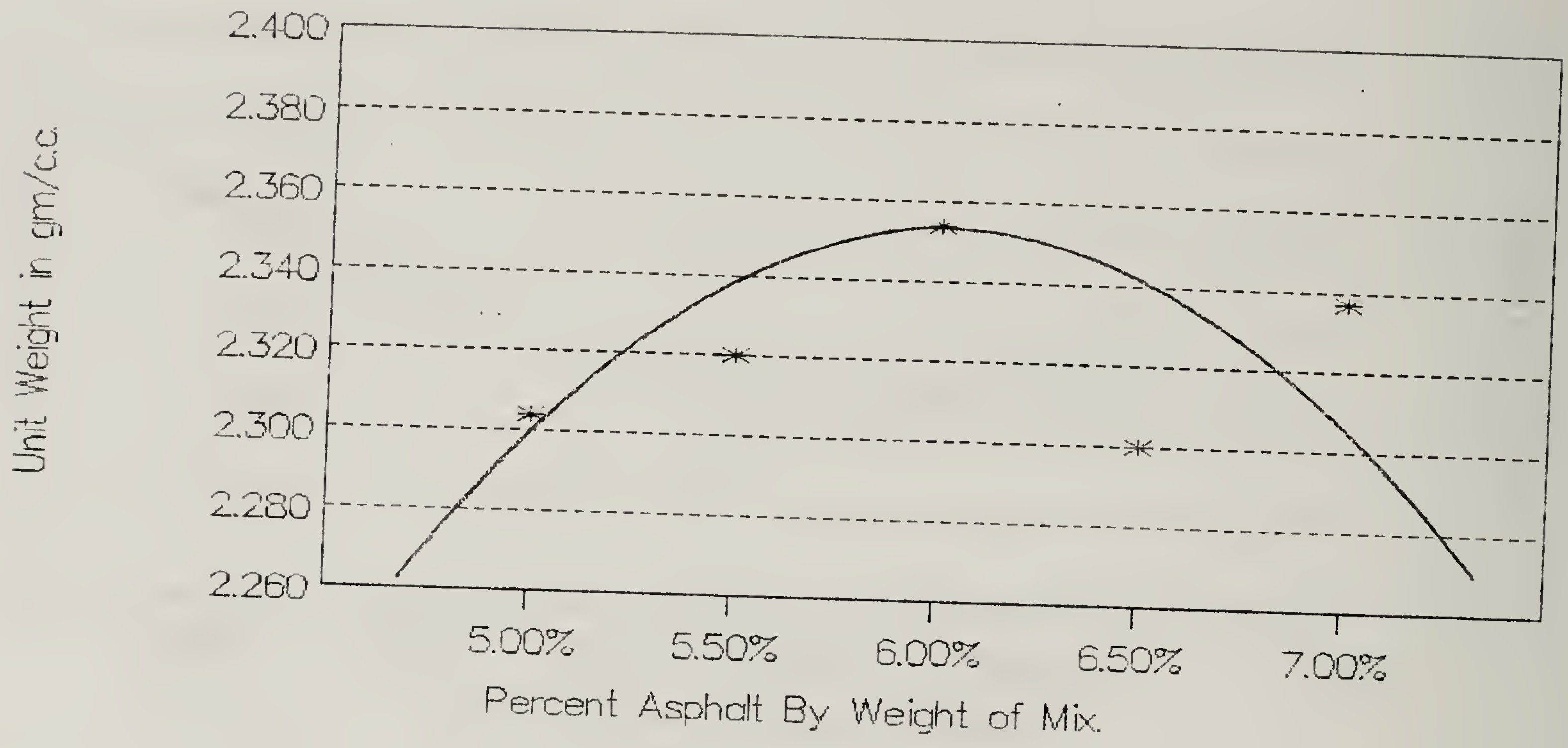
Polybilt Mod. Conoco–Stability

Split Aggregates Case II–50 Blows



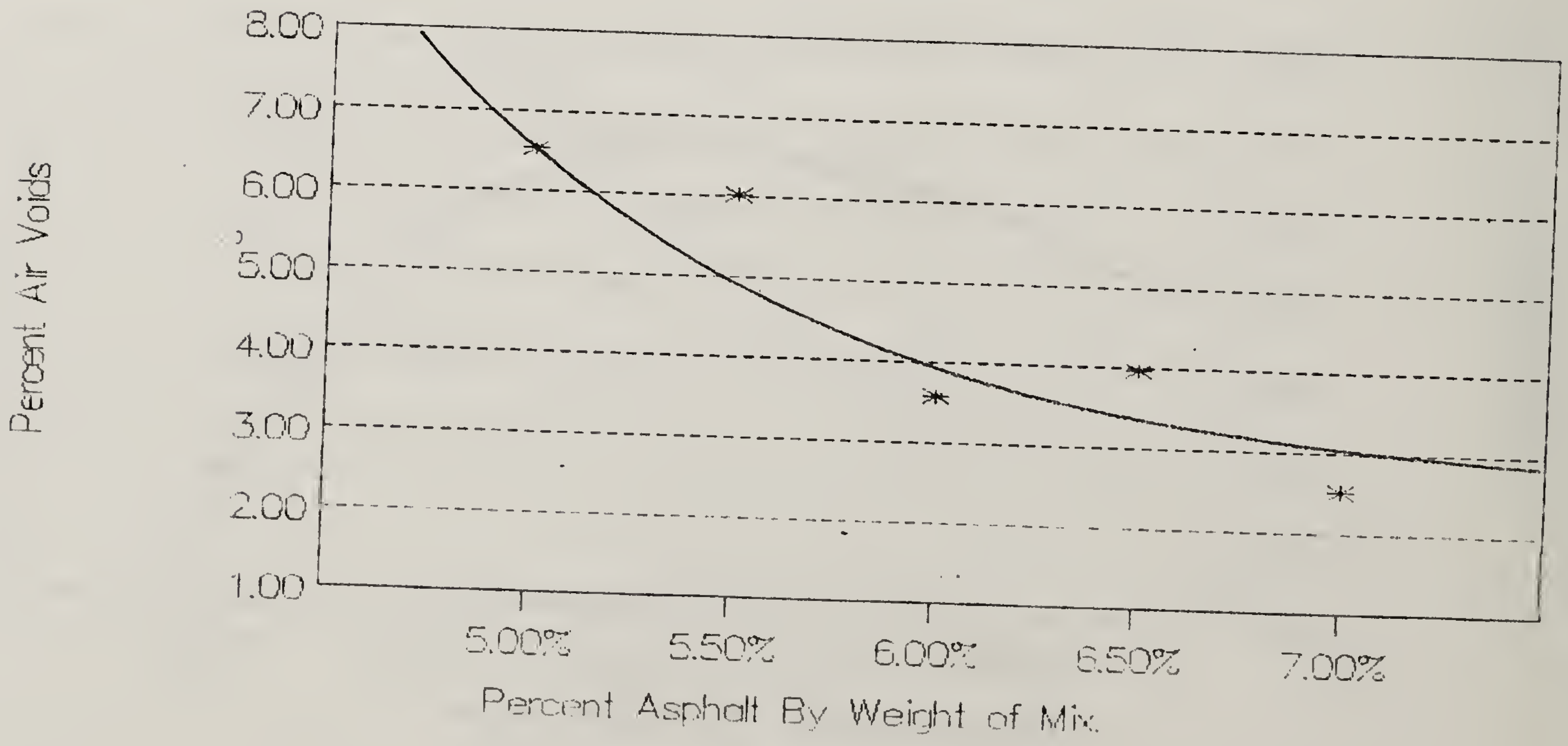
Polybilt Mod. Conoco–Unit Weight

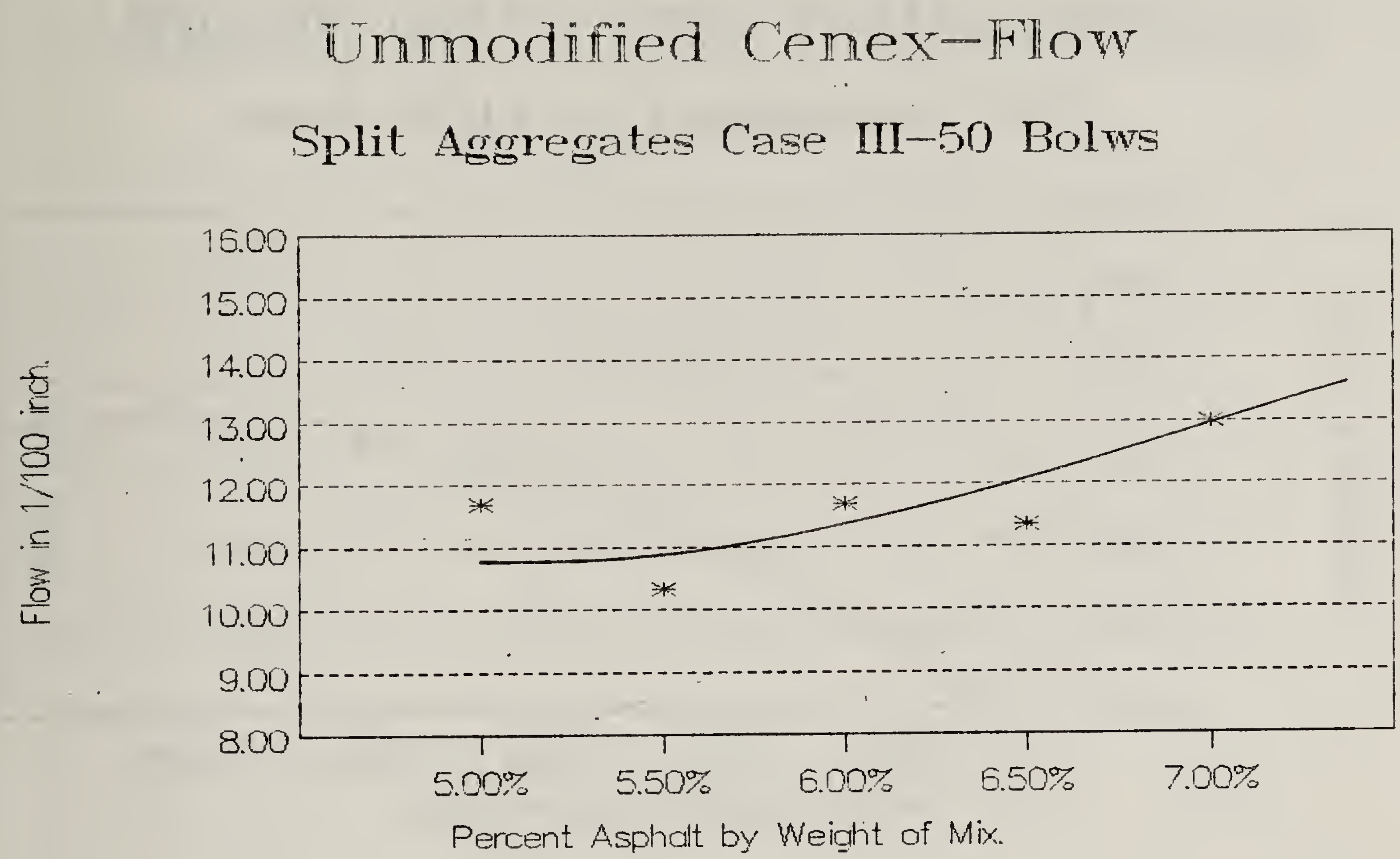
Split Aggregates Case II–50 Blows

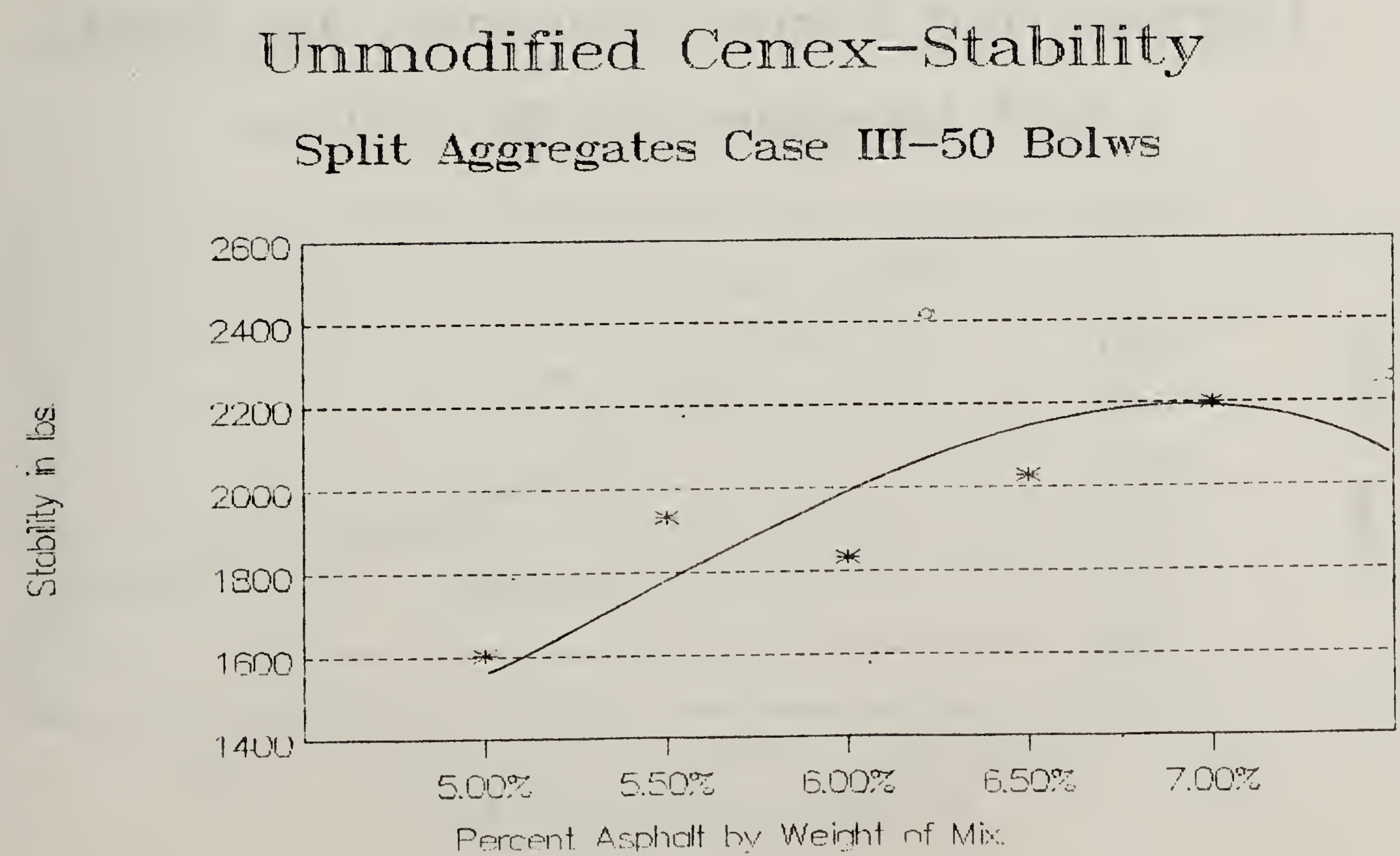


Polybilt Mod. Conoco–Air Voids

Split Aggregates Case II–50 Blows

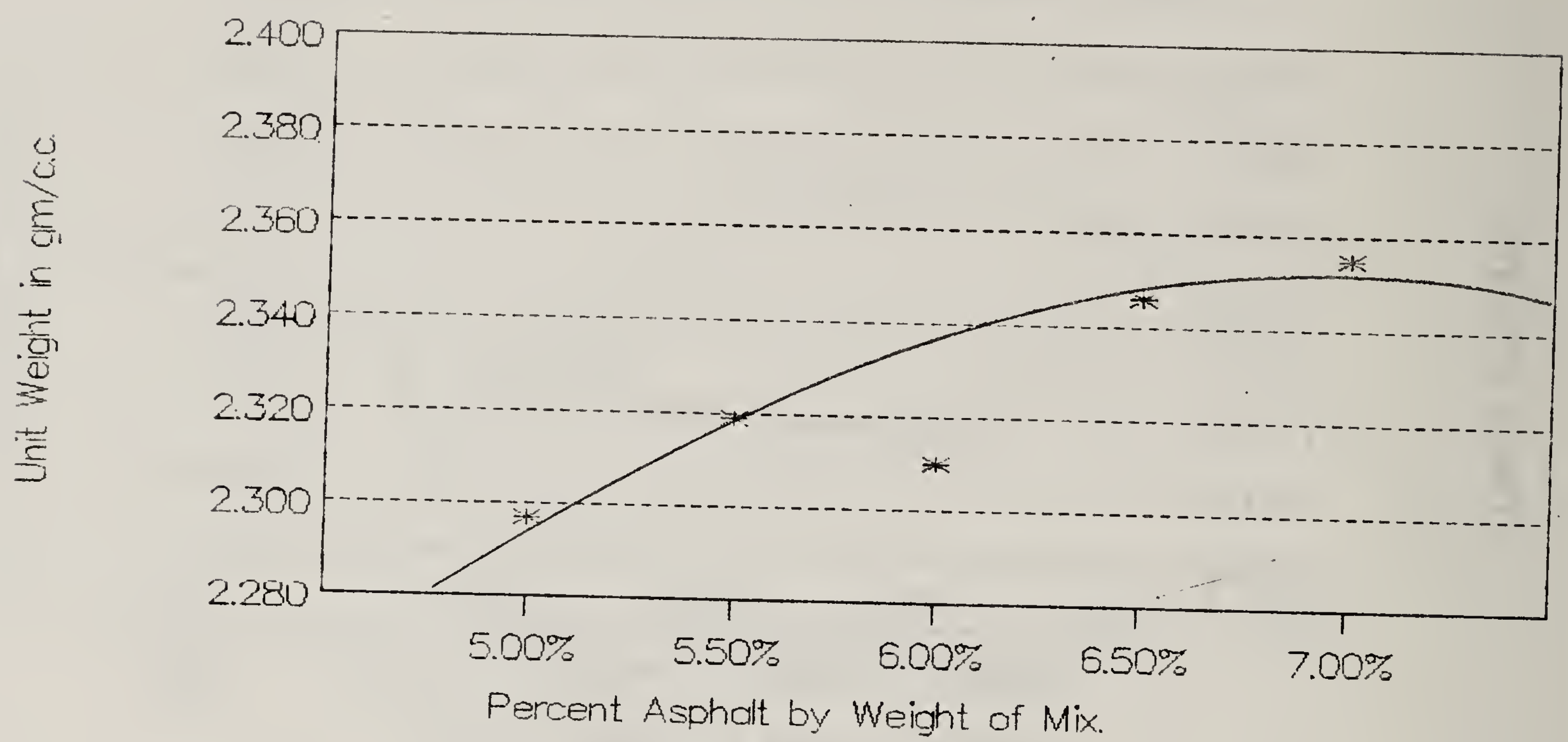



Unmodified Cenex—Flow
Split Aggregates Case III—50 Bolws
Flow in 1/100 inch.
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.


Unmodified Cenex—Stability
Split Aggregates Case III—50 Bolws
Stability in lbs.
2600
2400
2200
2000
1800
1600
1400
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.

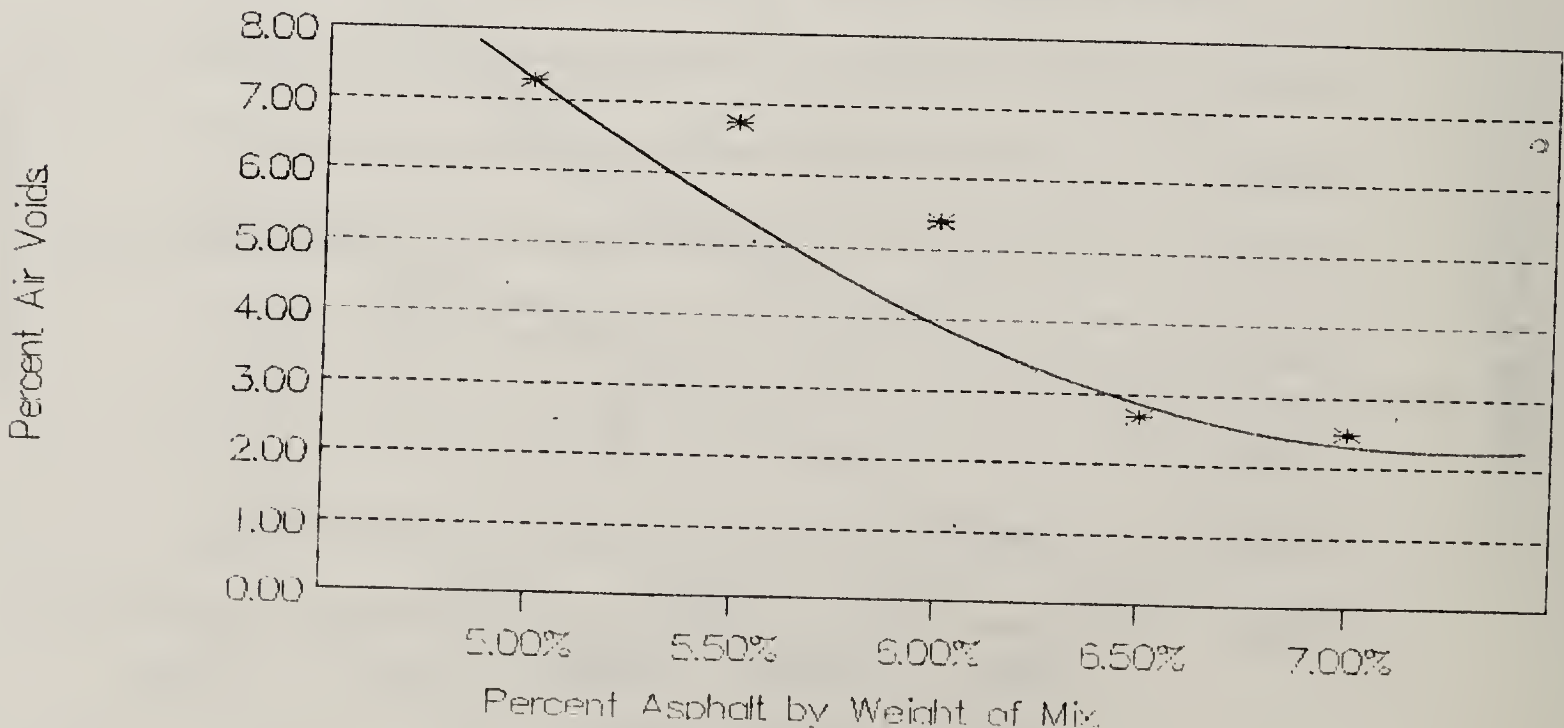
Unmodified Cenex–Unit Weight

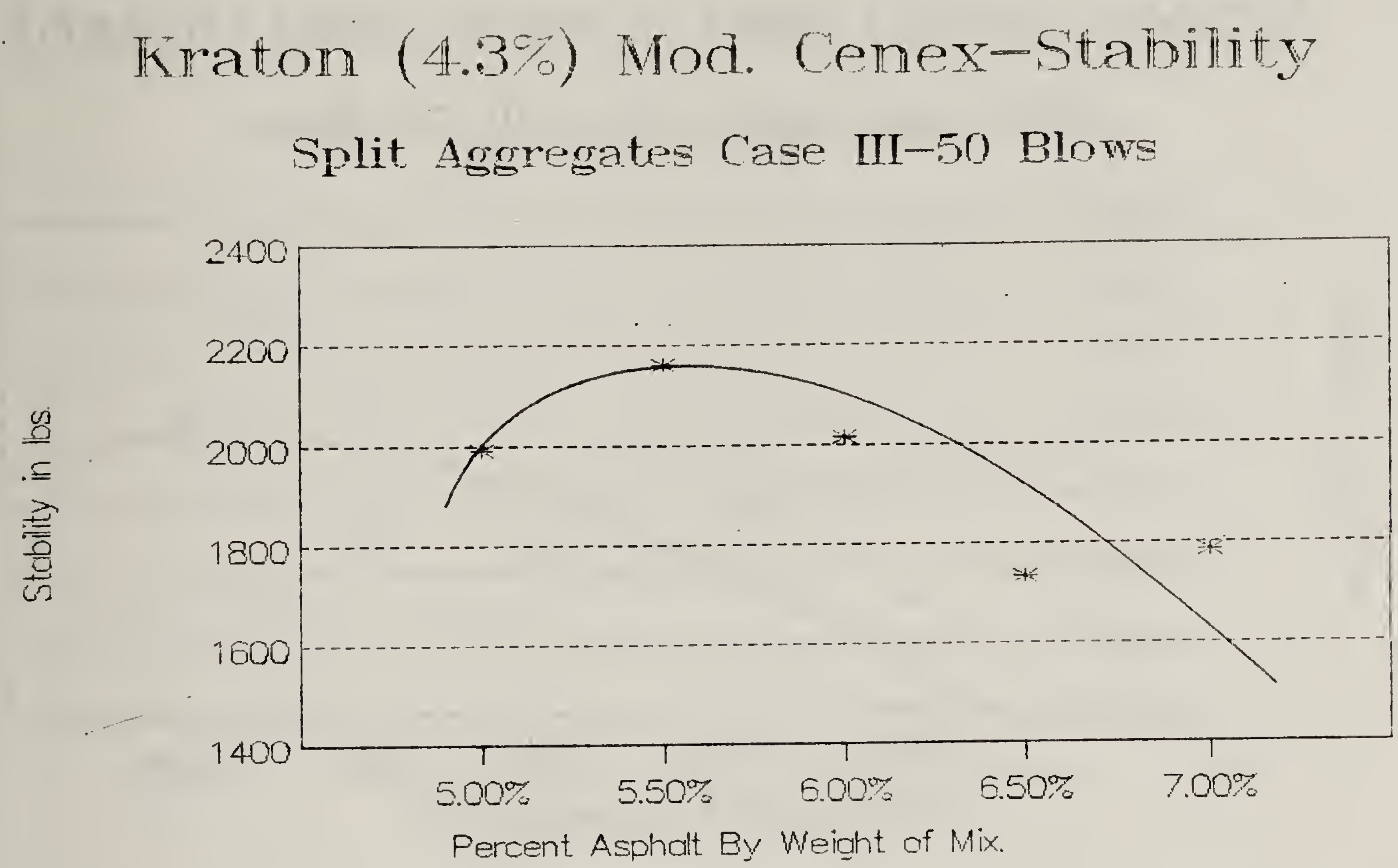
Split Aggregates Case III–50 Bolws

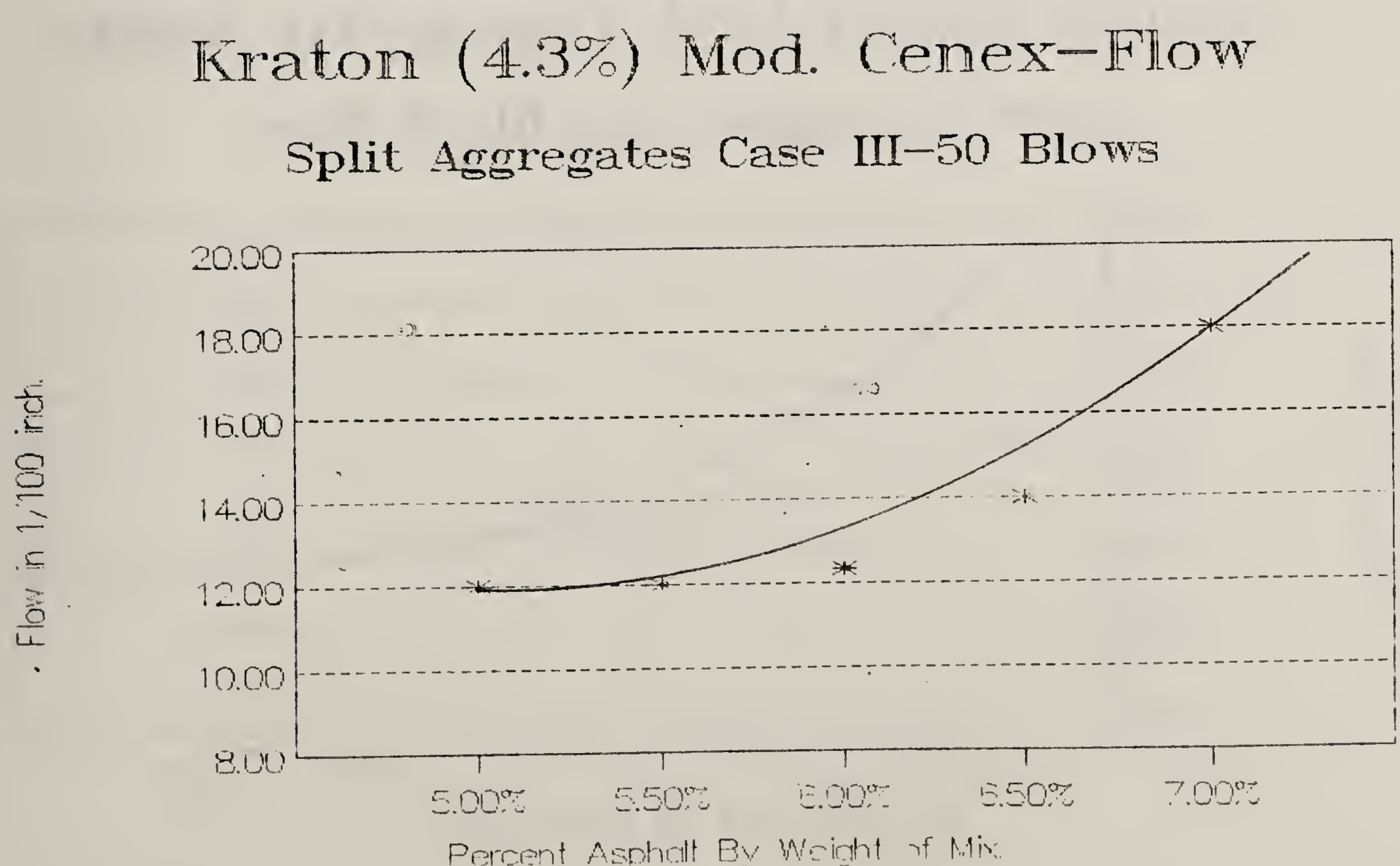


Unmodified Cenex–Percent Air Voids.

Split Aggregates Case III–50 Bolws

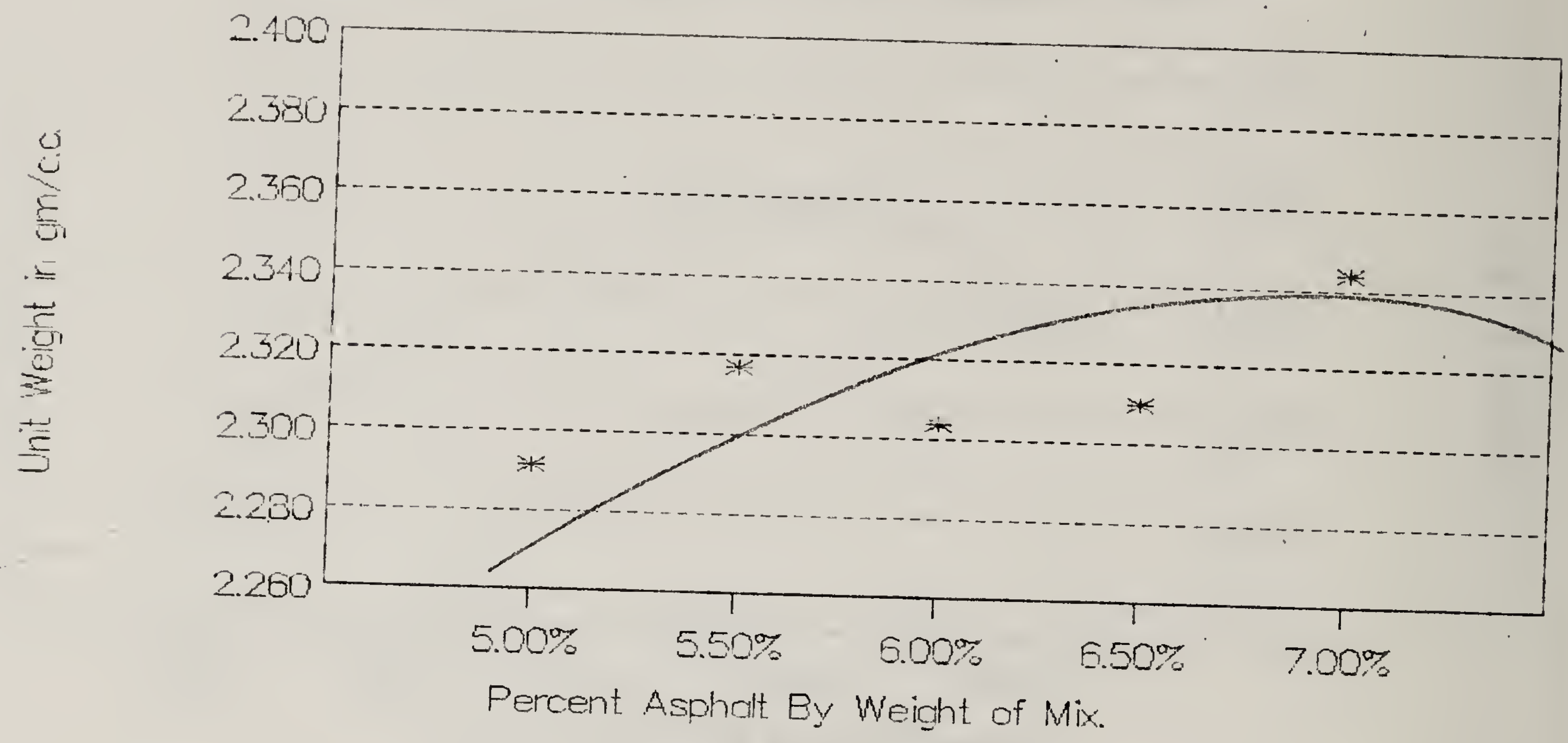



Kraton (4.3%) Mod. Cenex–Stability
Split Aggregates Case III–50 Blows
Stability in lbs.
2400
2200
2000
1800
1600
1400
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Kraton (4.3%) Mod. Cenex–Flow
Split Aggregates Case III–50 Blows
Flow in 1/100 inch.
20.00
18.00
16.00
14.00
12.00
10.00
8.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

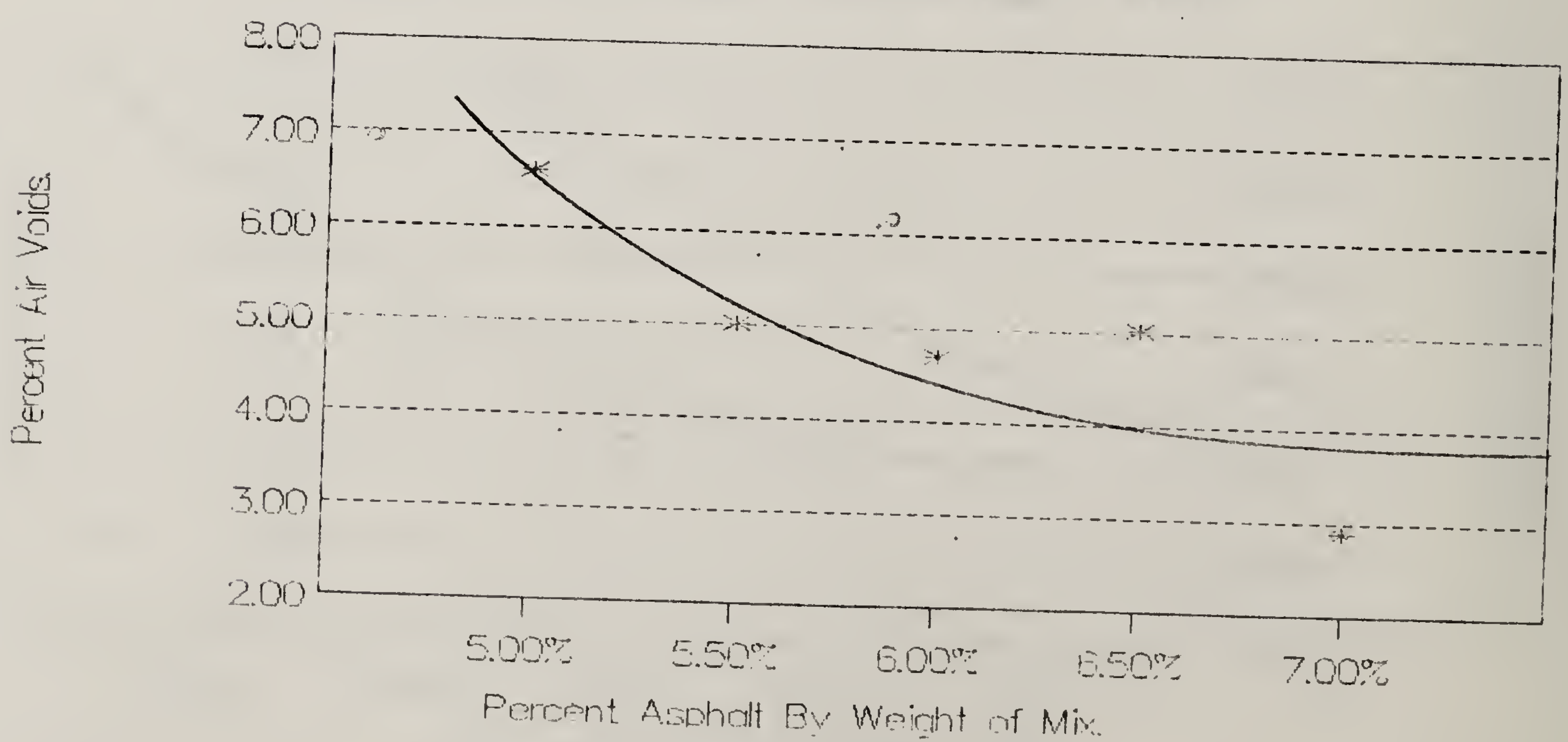
Kraton (4.3%) Mod. Cenex-Unit Weight

Split Aggregates Case III-50 Blows



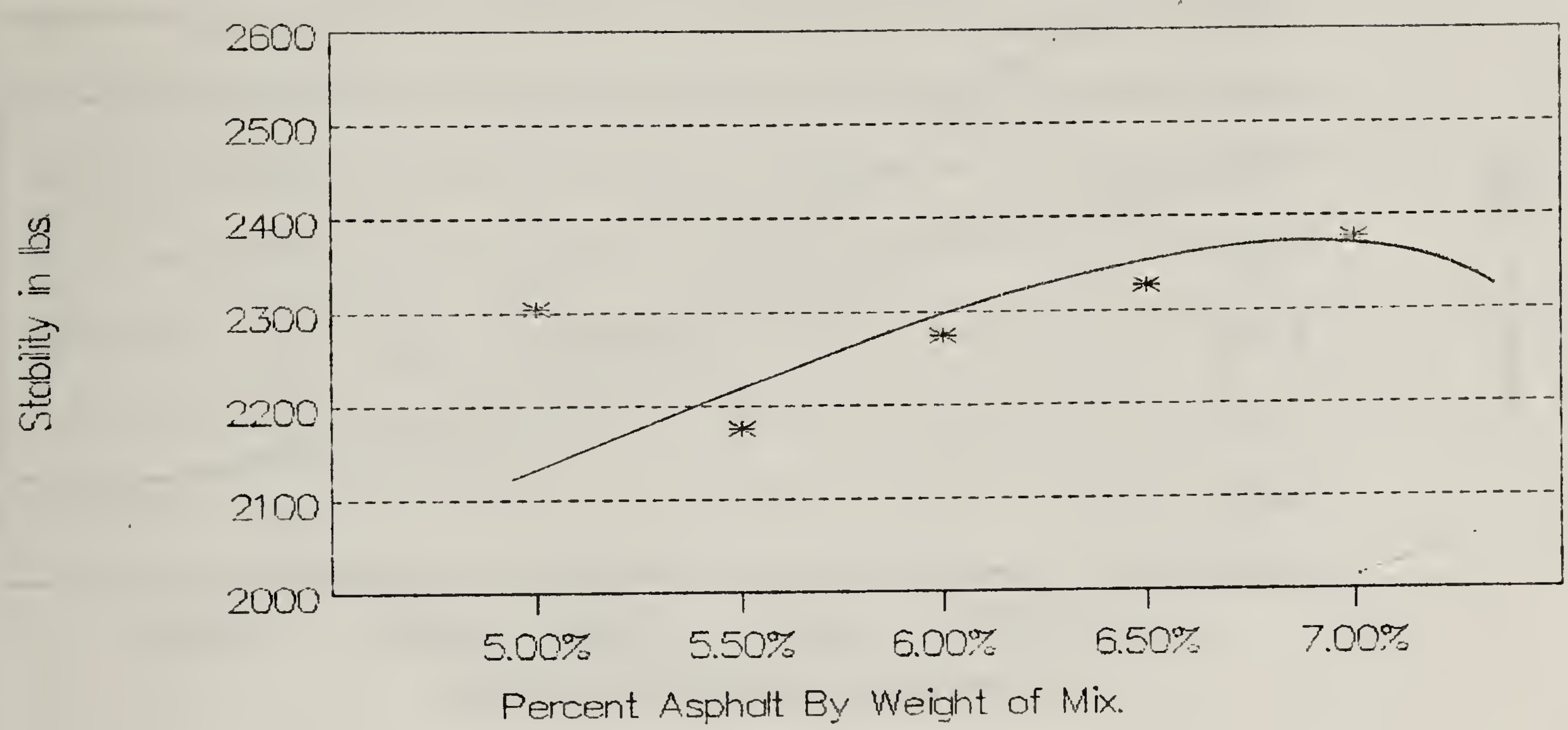
Kraton (4.3%) Mod. Cenex-Air Voids

Split Aggregates Case III-50 Blows



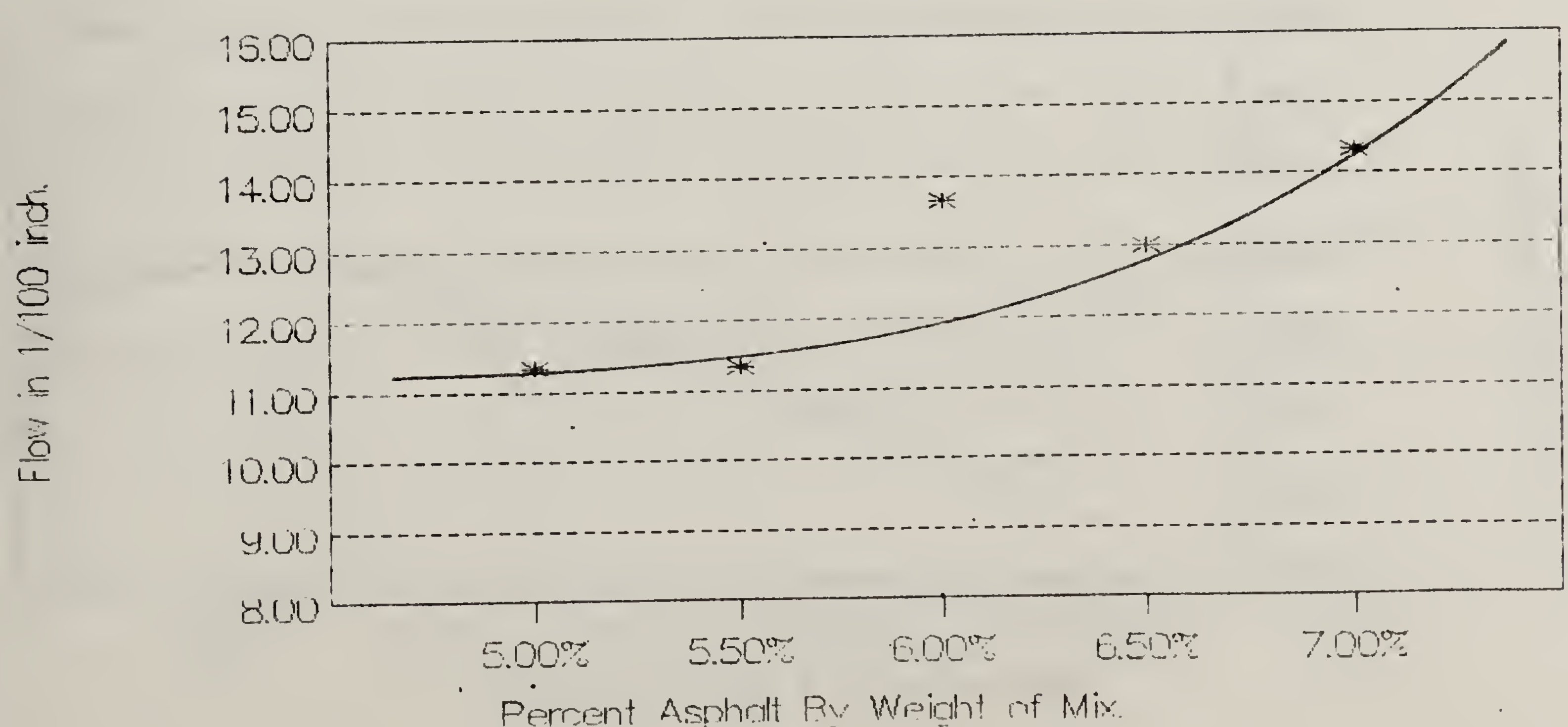
Kraton (6%) Mod. Cenex–Stability

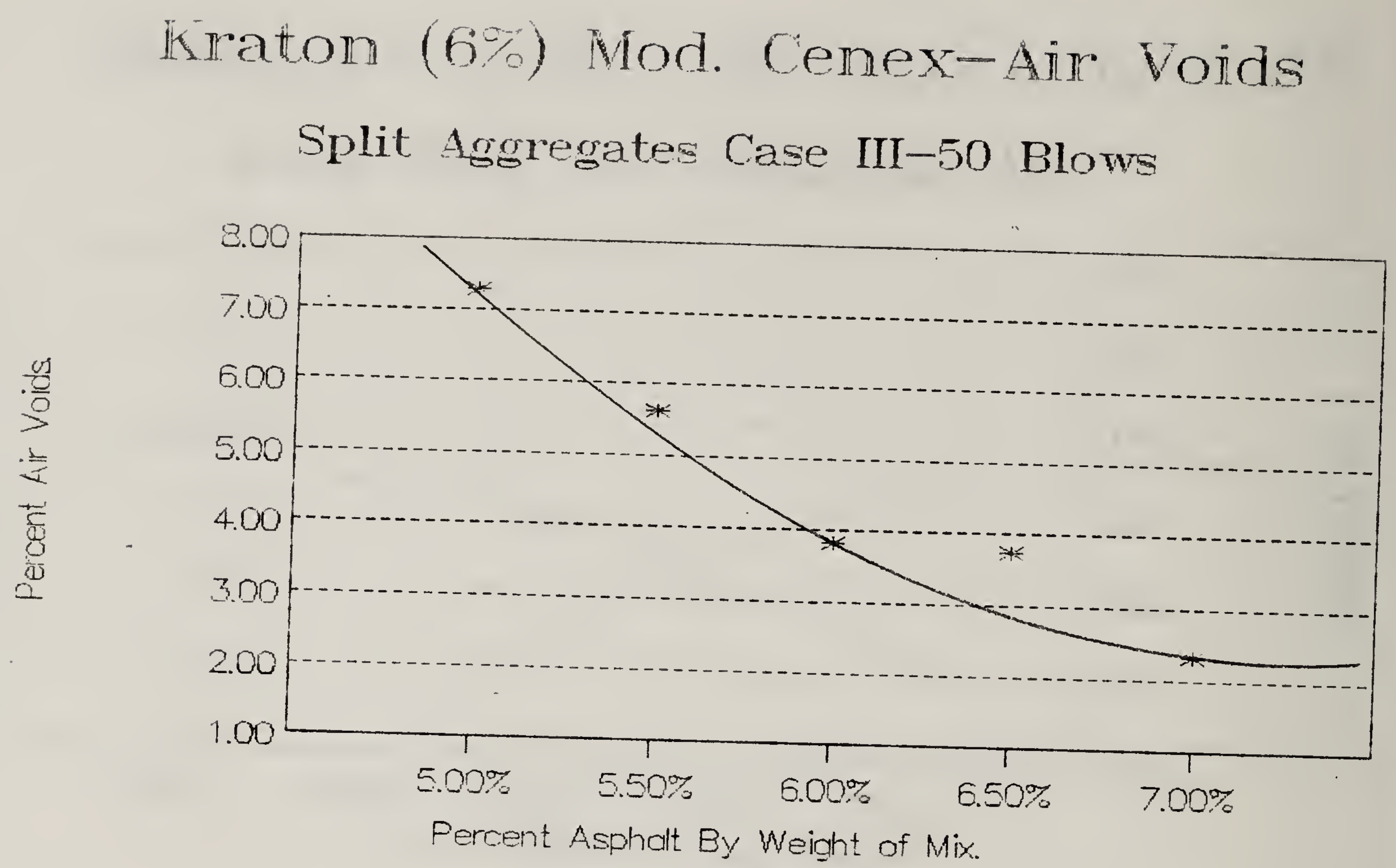
Split Aggregates Case III–50 Blows



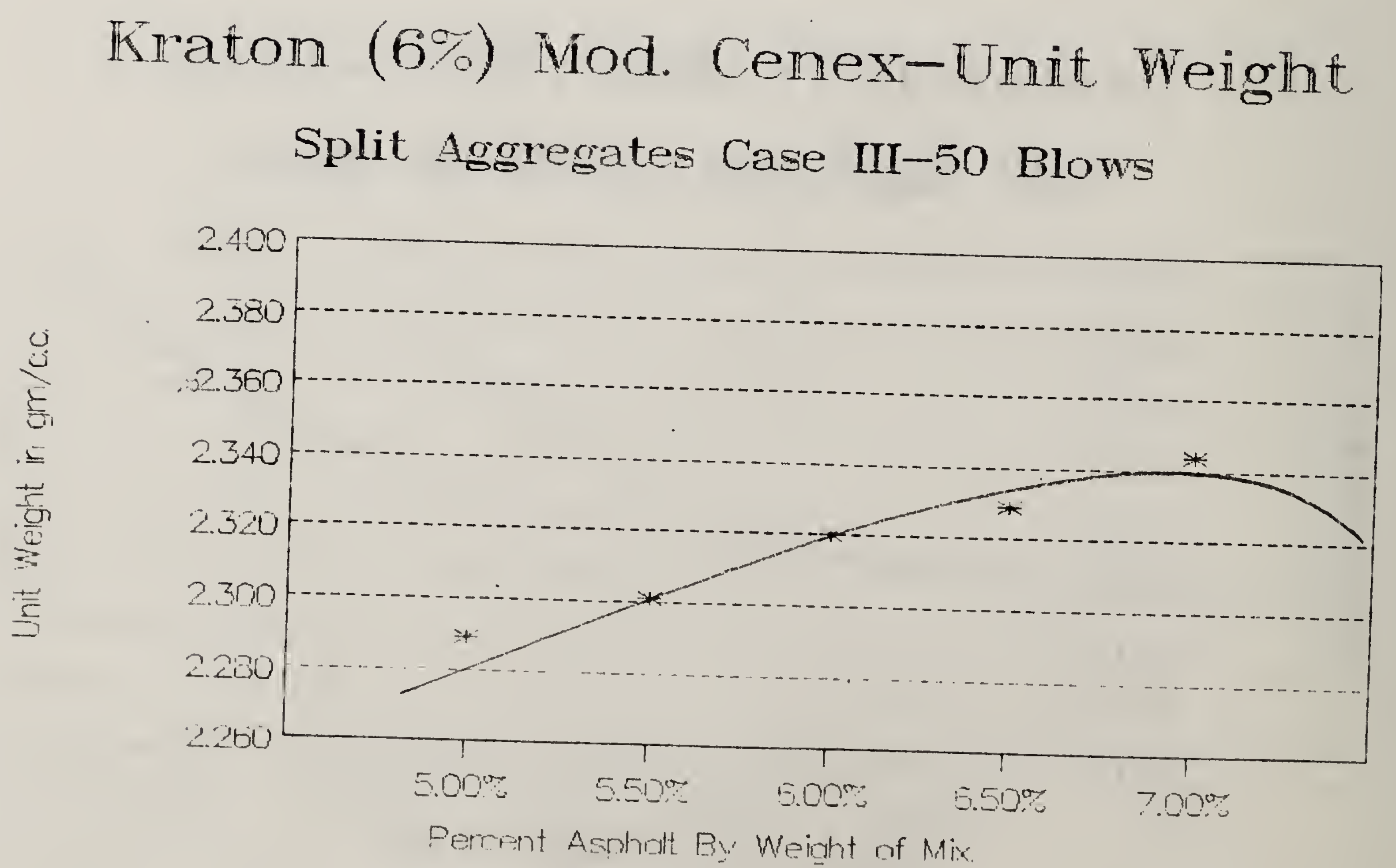
Kraton (6%) Mod. Cenex–Flow

Split Aggregates Case III–50 Blows





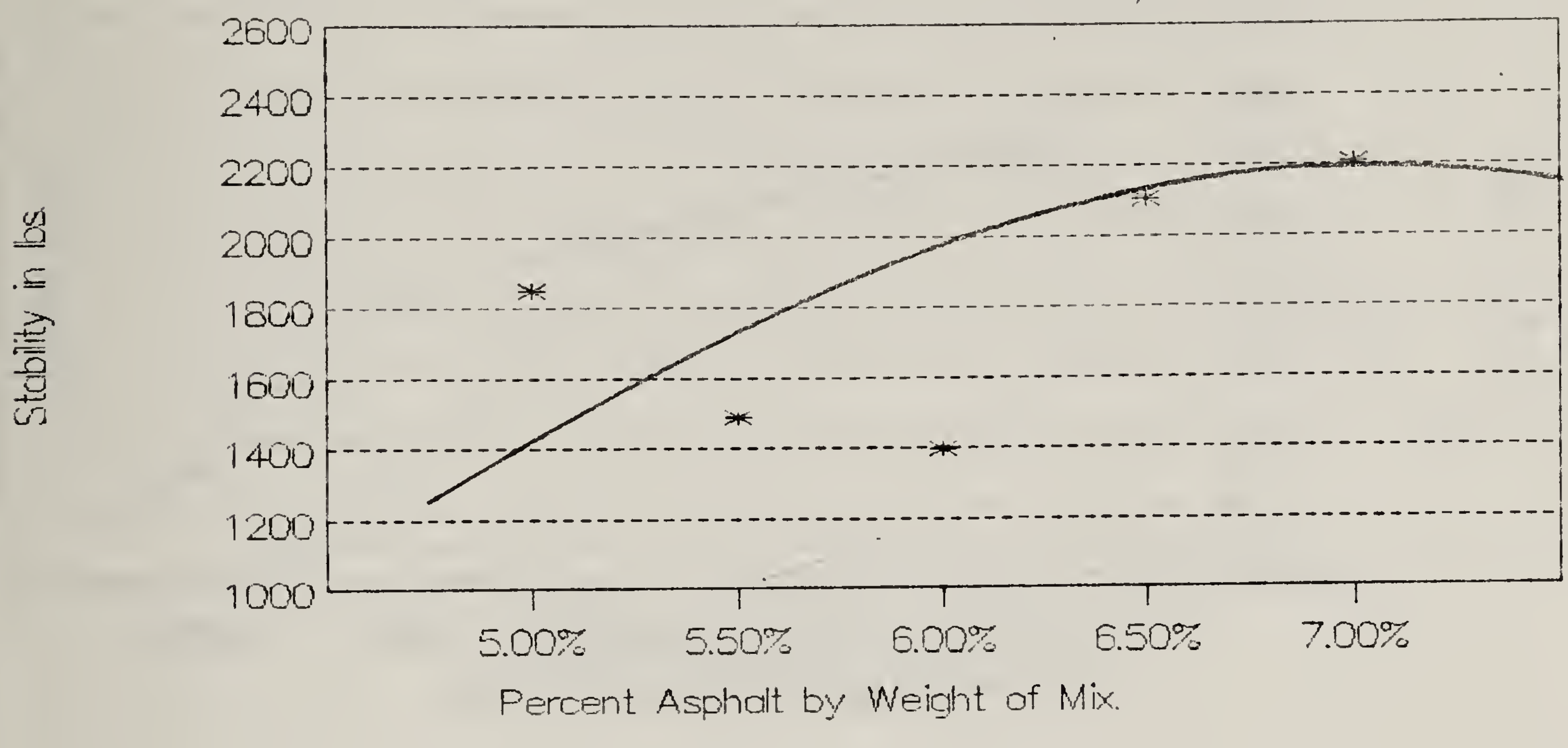
Kraton (6%) Mod. Cenex-Air Voids
Split Aggregates Case III-50 Blows
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
Percent Air Voids
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.



Kraton (6%) Mod. Cenex-Unit Weight
Split Aggregates Case III-50 Blows
2.400
2.380
2.360
2.340
2.320
2.300
2.280
2.260
Unit Weight in gm/c.c.
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

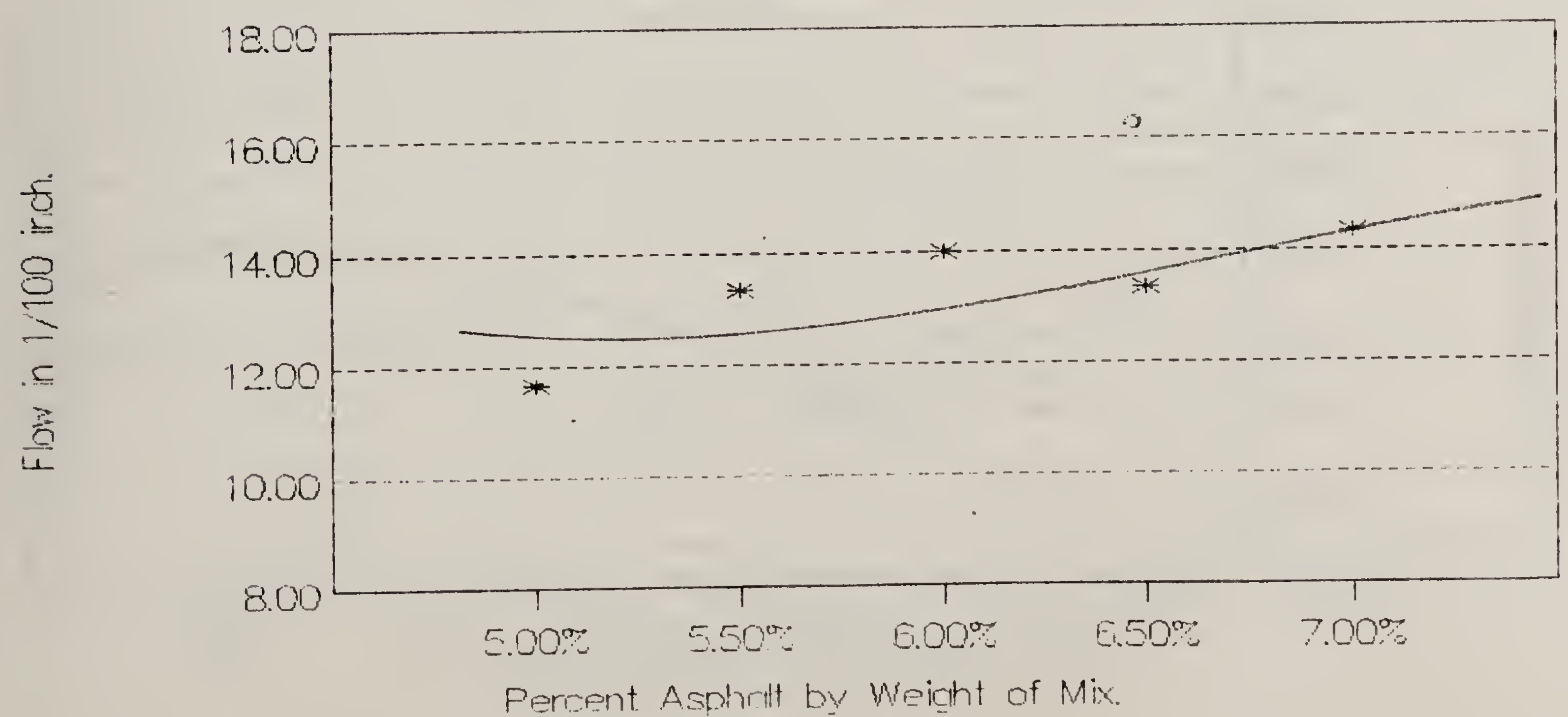
Polybilt Mod. Cenex–Stability

Split Aggregates Case III–50 Bolws



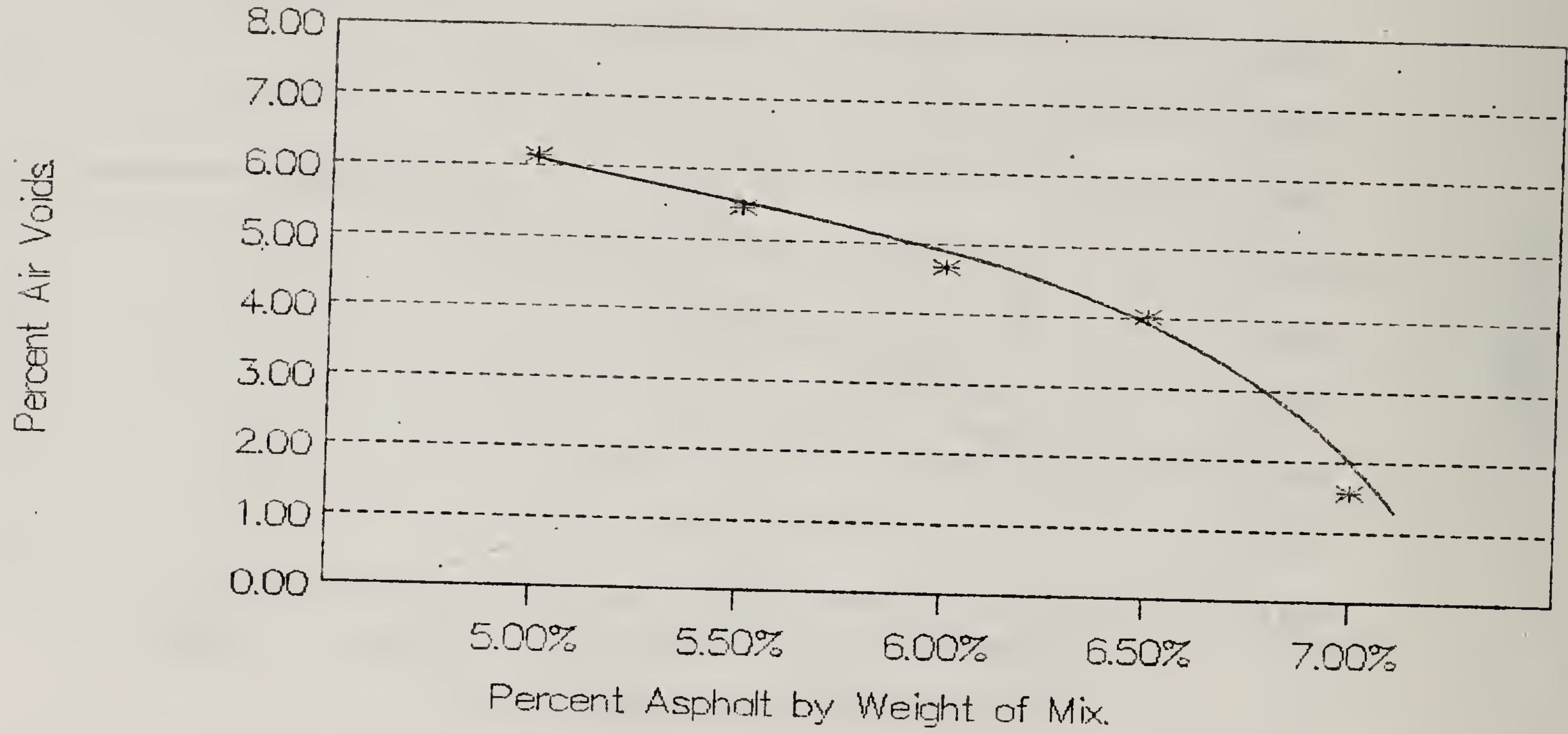
Polybilt Mod. Cenex–Flow

Split Aggregates Case III–50 Bolws



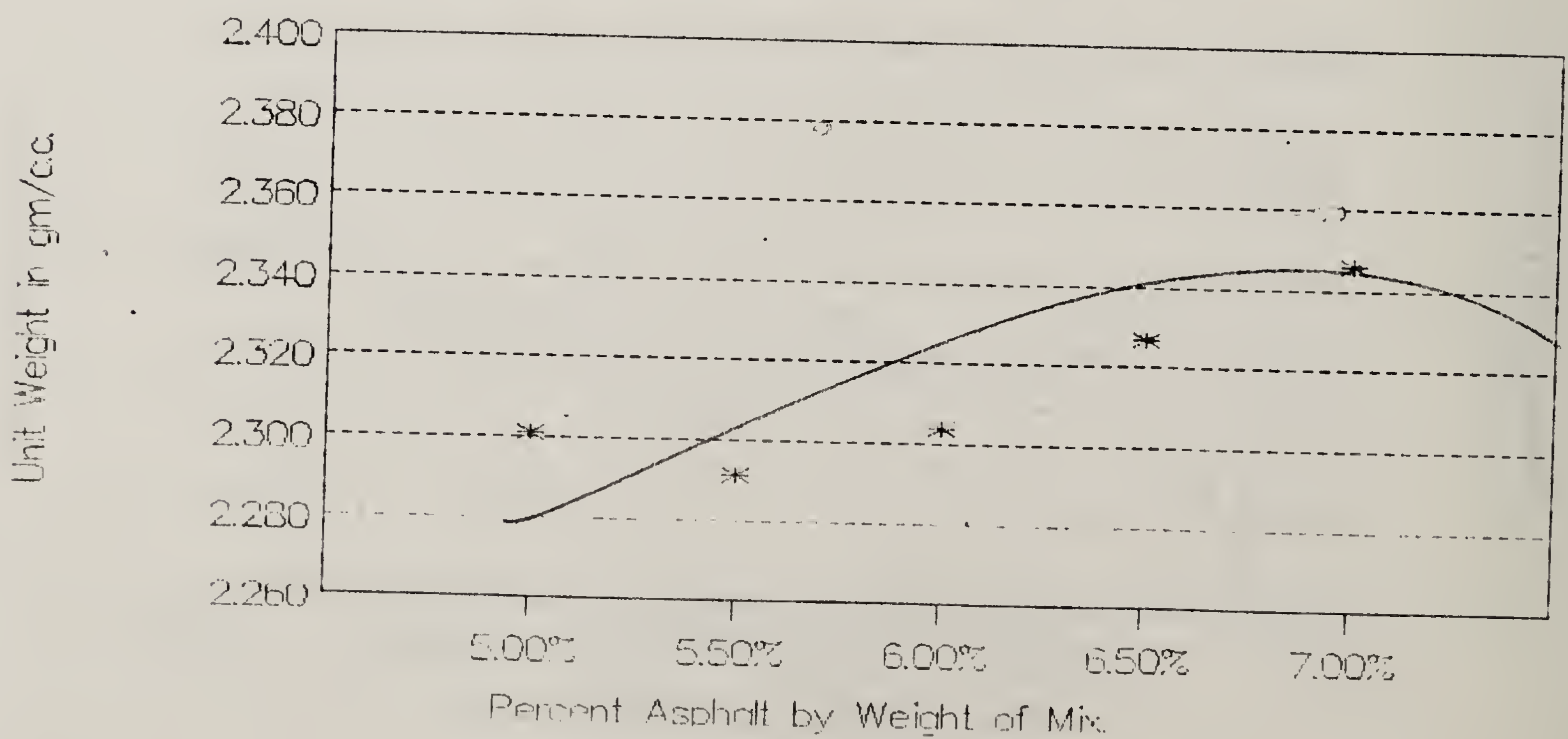
Polybilt Mod. Cenex–Percent Air Voids.

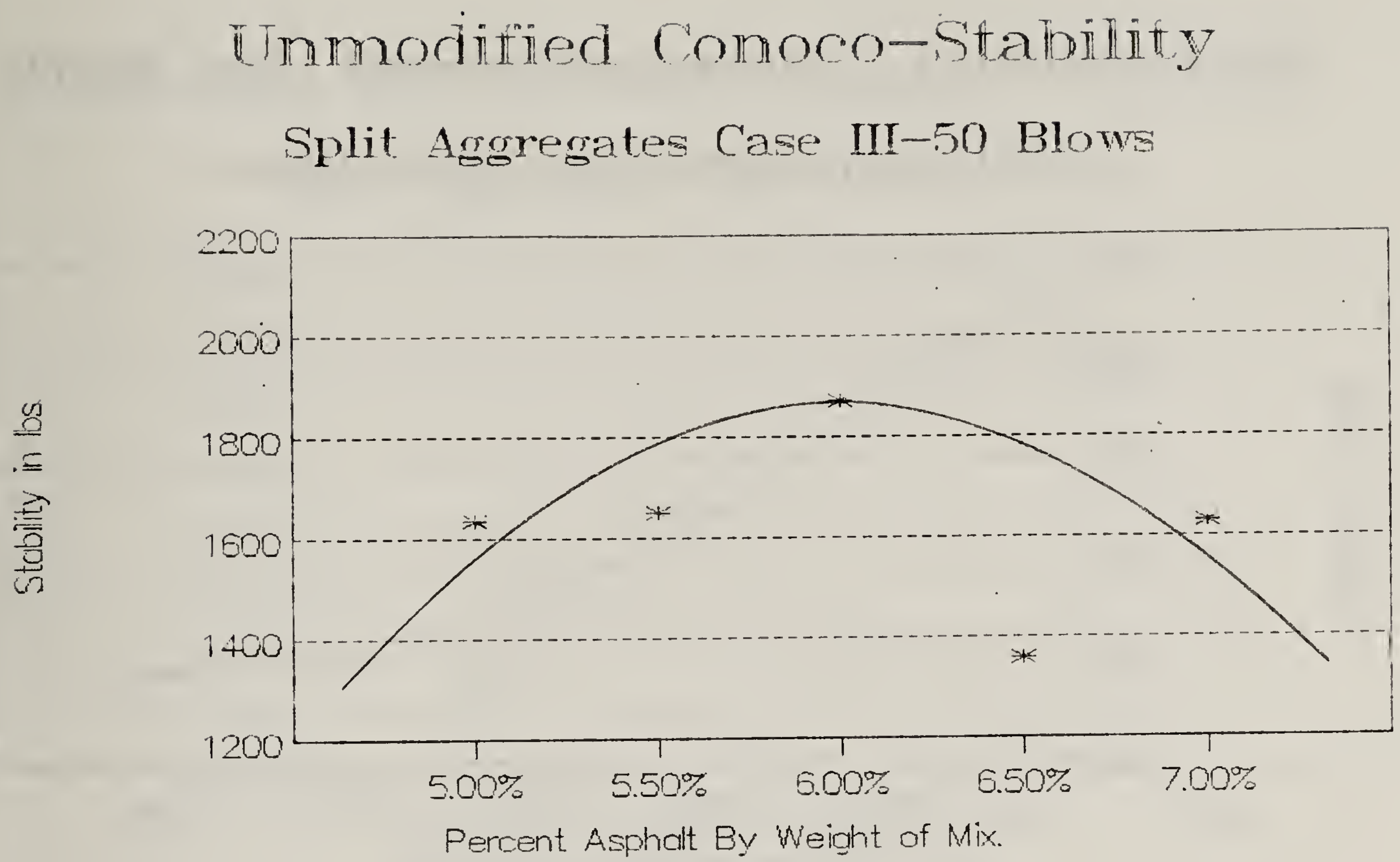
Split Aggregates Case III–50 Bolws

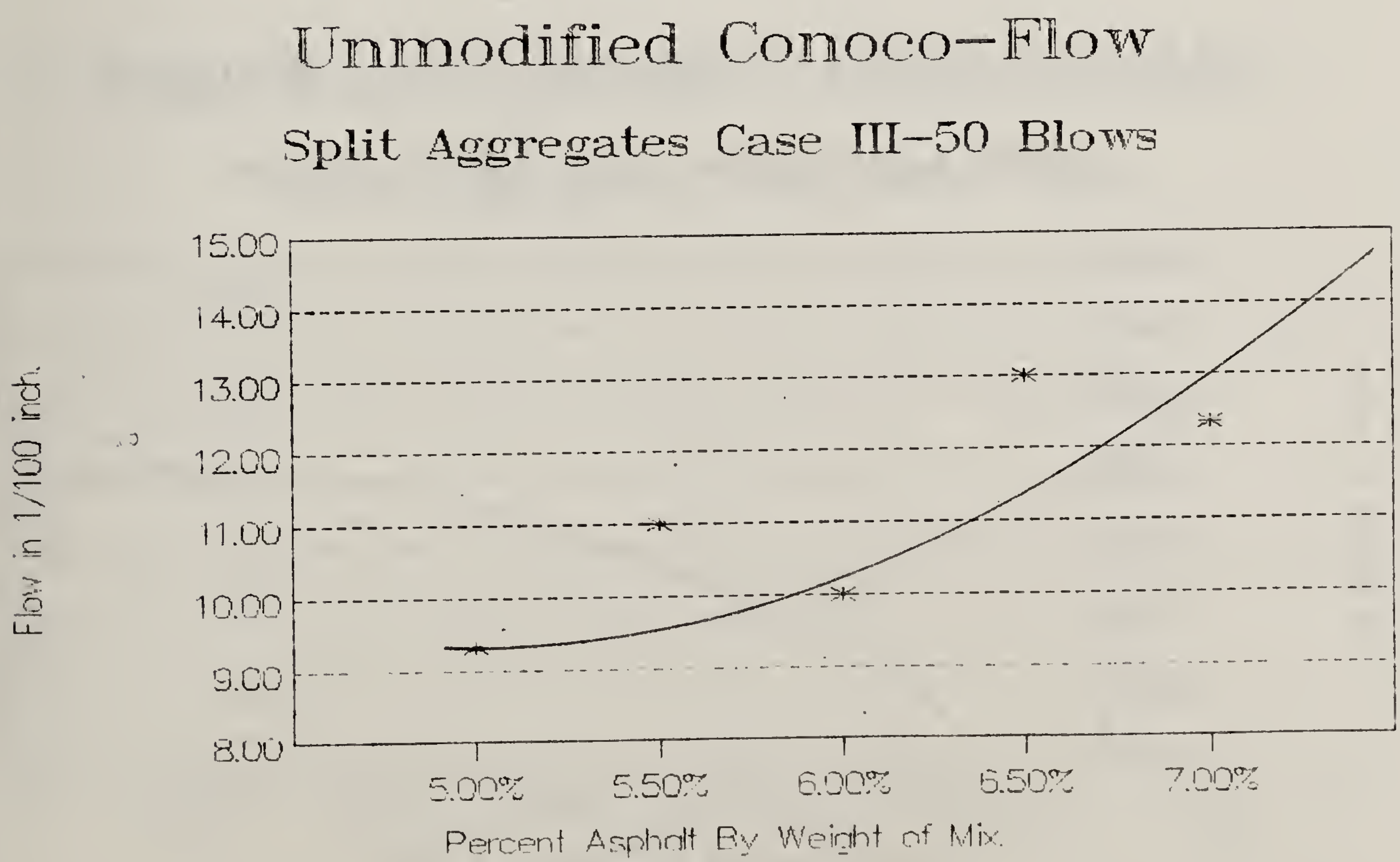


Polybilt Mod. Cenex–Unit Weight

Split Aggregates Case III–50 Bolws

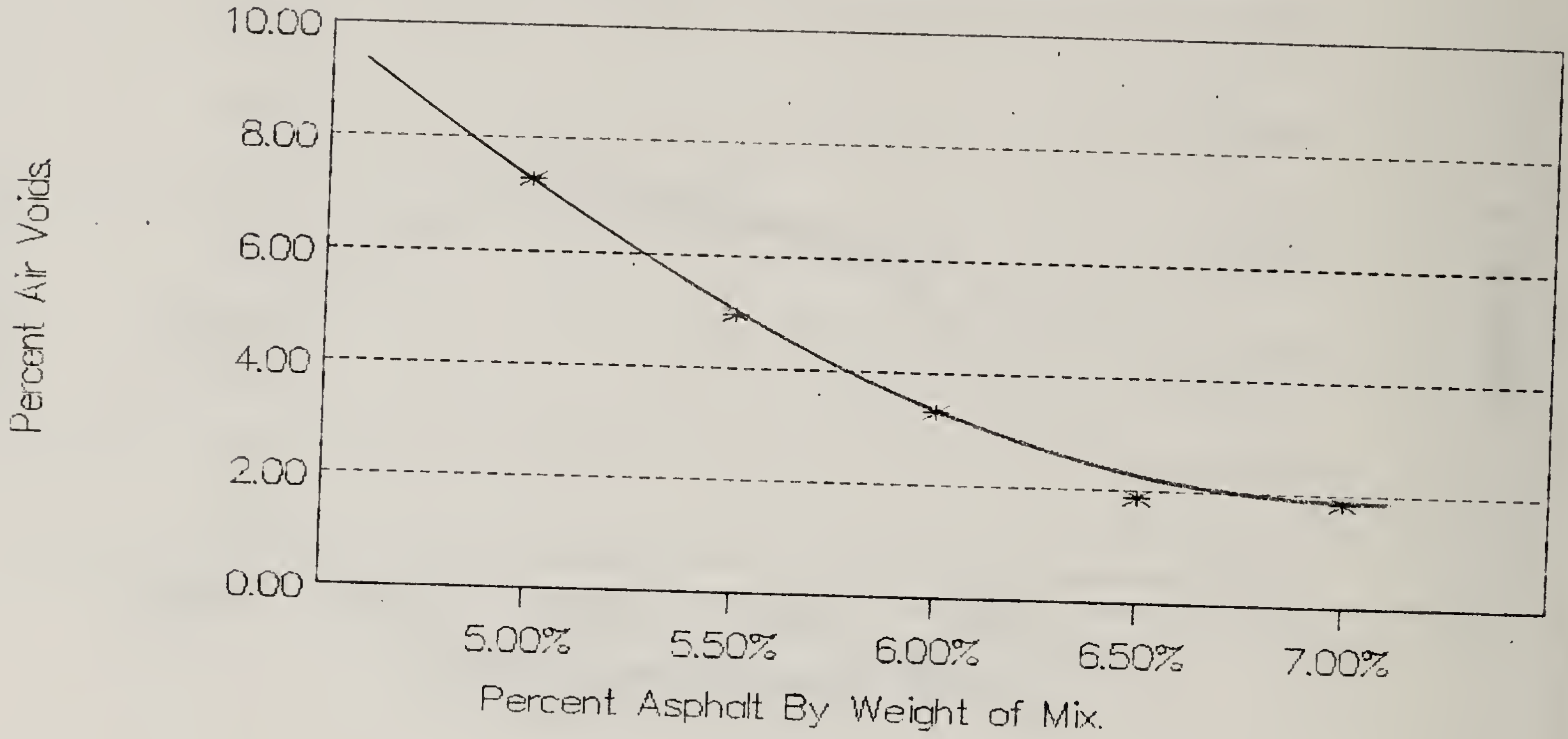



Unmodified Conoco-Stability
Split Aggregates Case III-50 Blows
Stability in lbs
2200
2000
1800
1600
1400
1200
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.


Unmodified Conoco-Flow
Split Aggregates Case III-50 Blows
Flow in 1/100 inch.
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt By Weight of Mix.

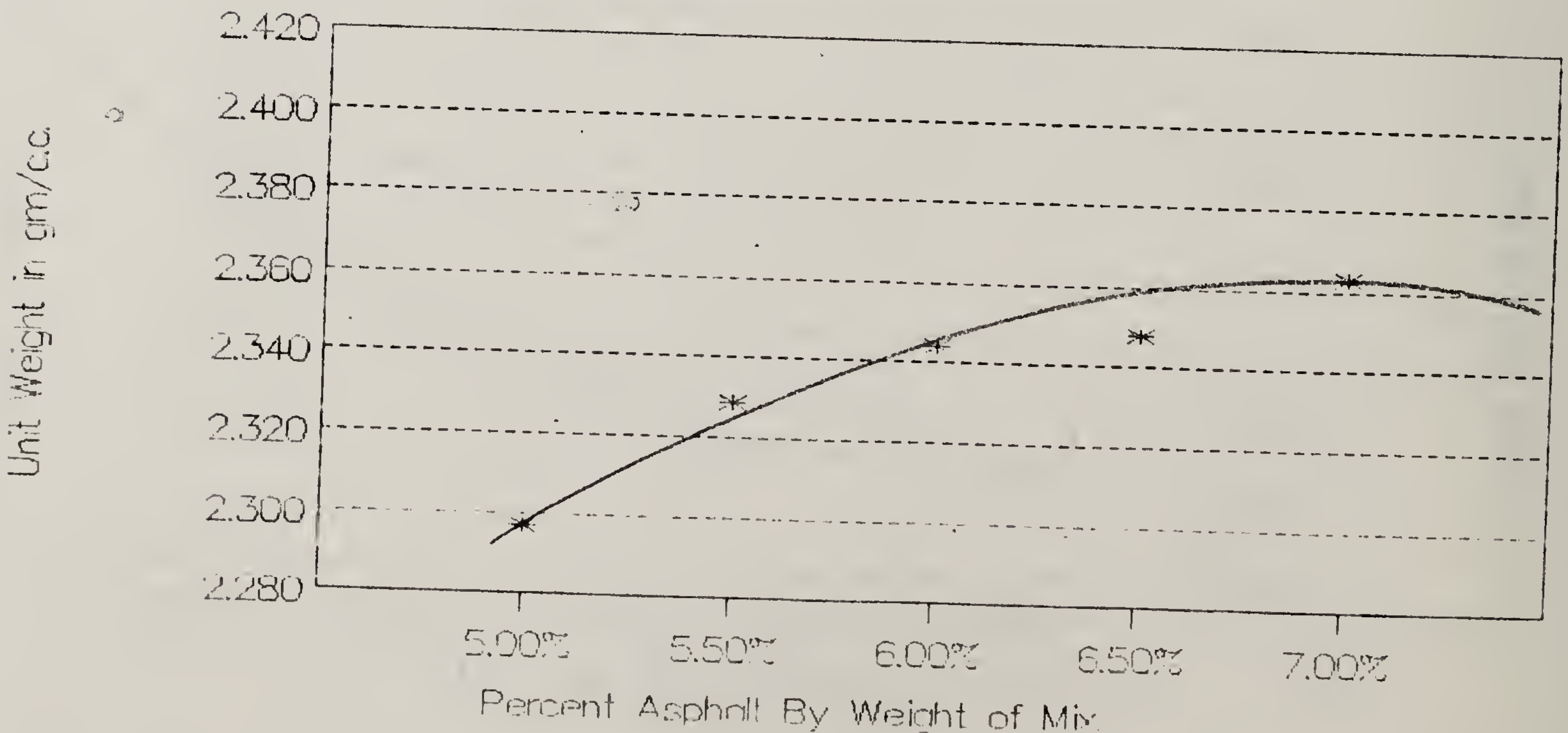
Unmodified Conoco-Percent Air Voids

Split Aggregates Case III-50 Blows



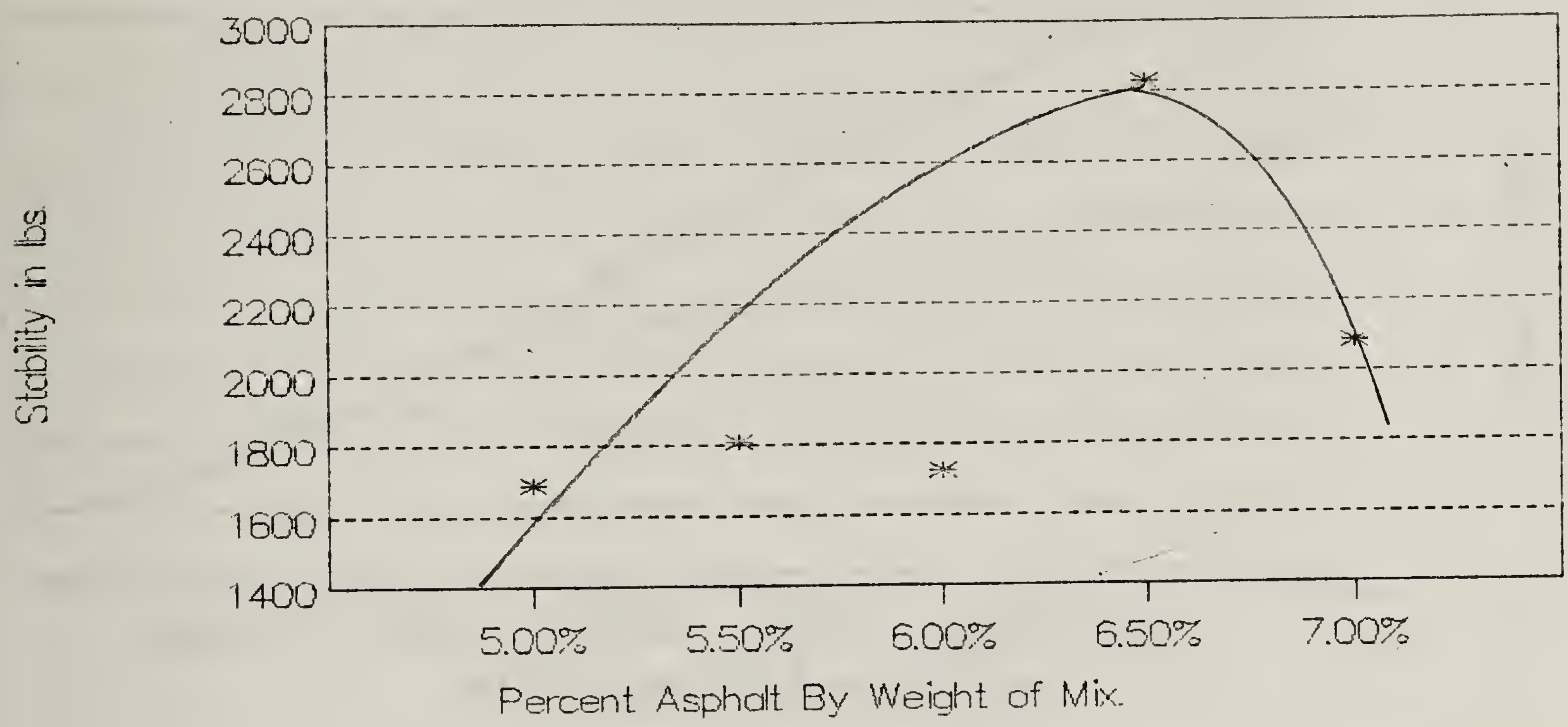
Unmodified Conoco-Unit Weight

Split Aggregates Case III-50 Blows



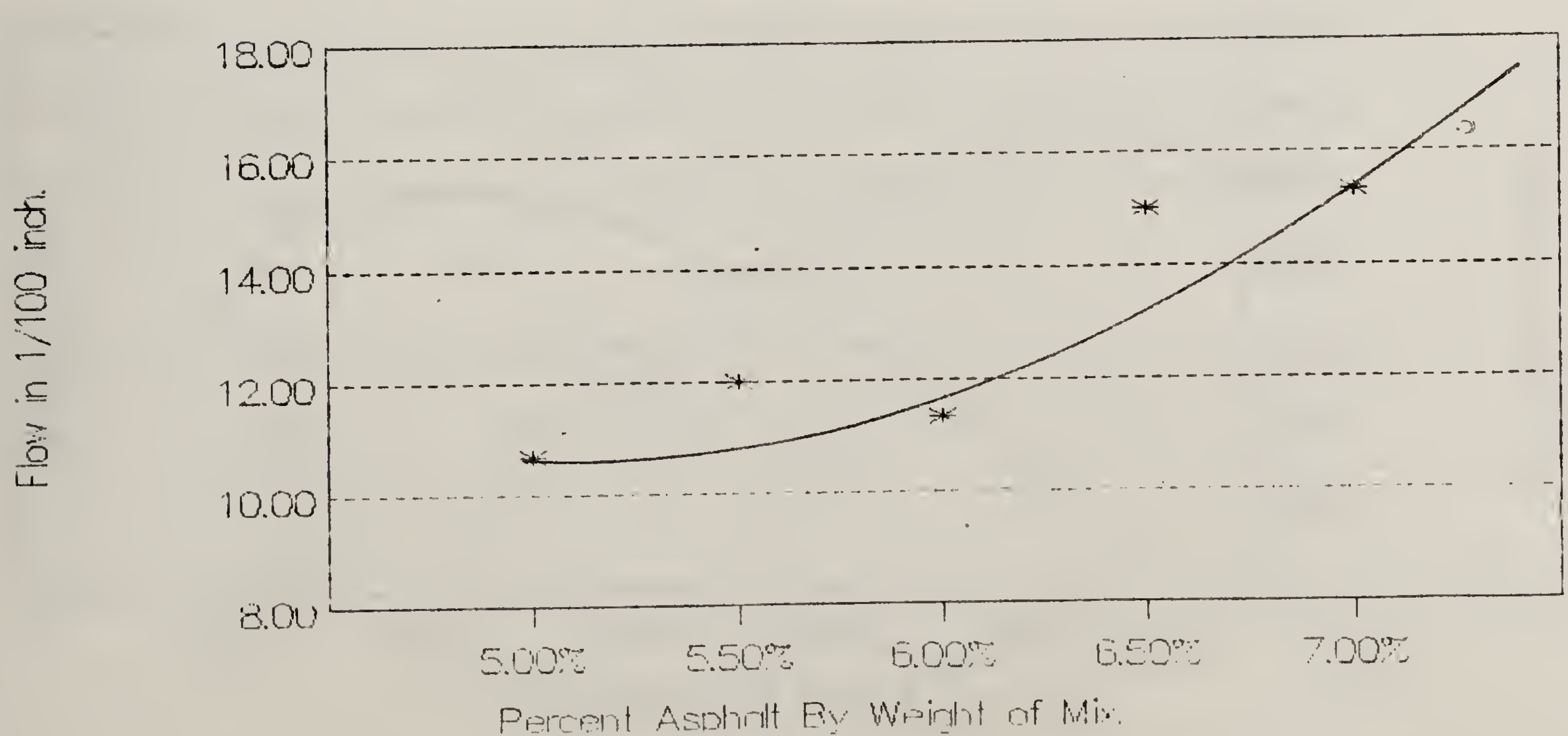
Kraton (4.3%) Mod. Conoco-Stability

Split Aggregates Case III-50 Blows



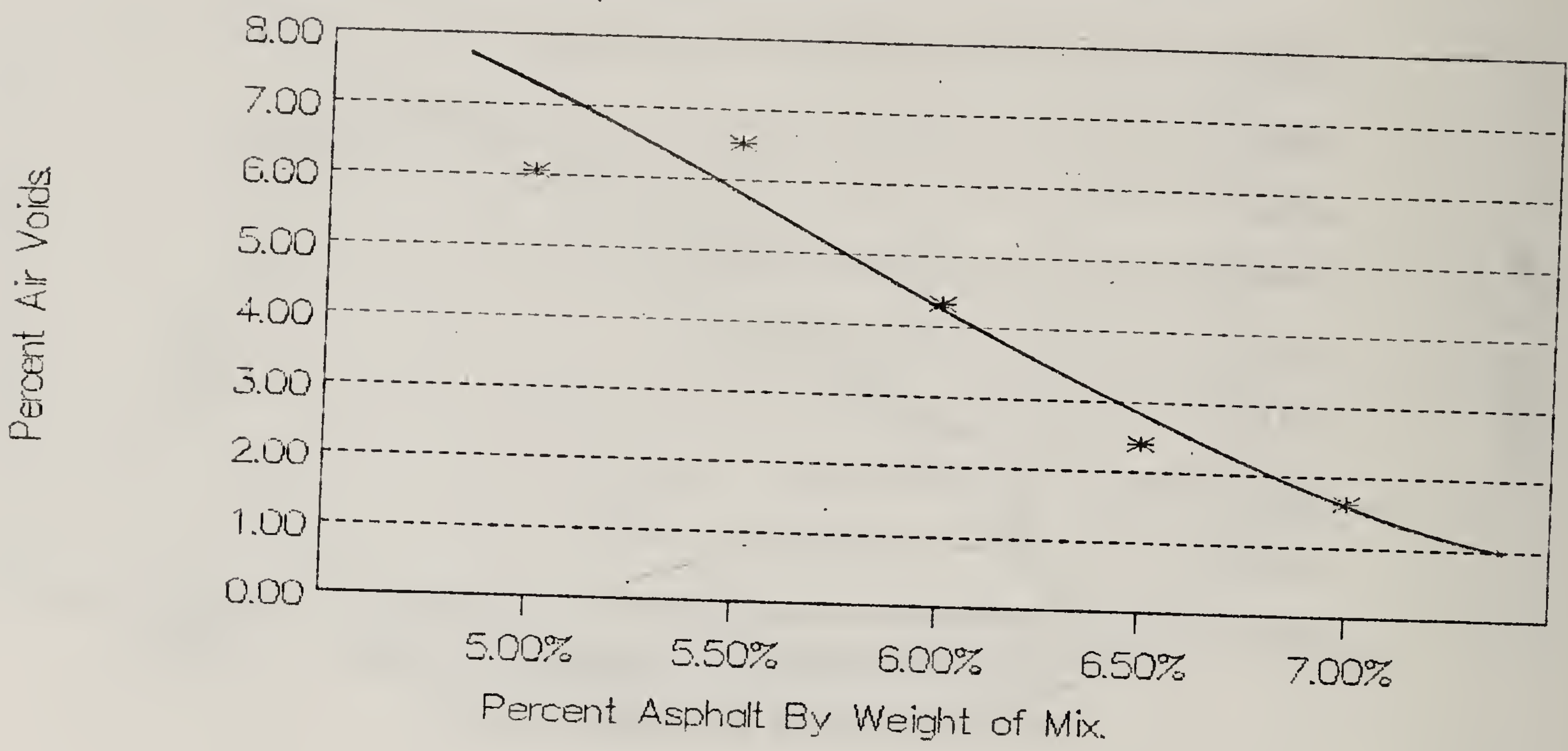
Kraton (4.3%) Mod. Conoco-Flow

Split Aggregates Case III-50 Blows



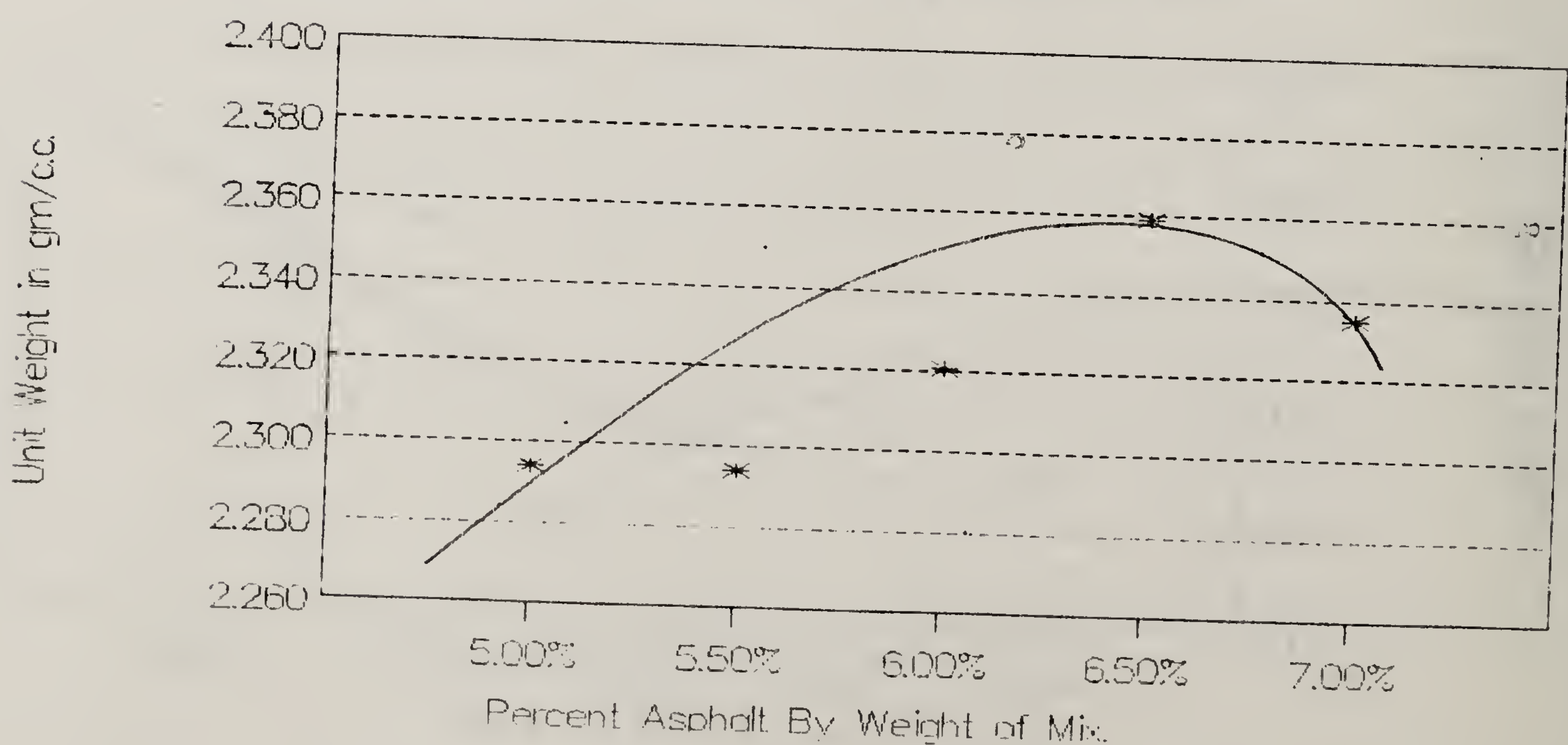
Kraton (4.3%) Mod. Conoco–Air Voids

Split Aggregates Case III–50 Blows



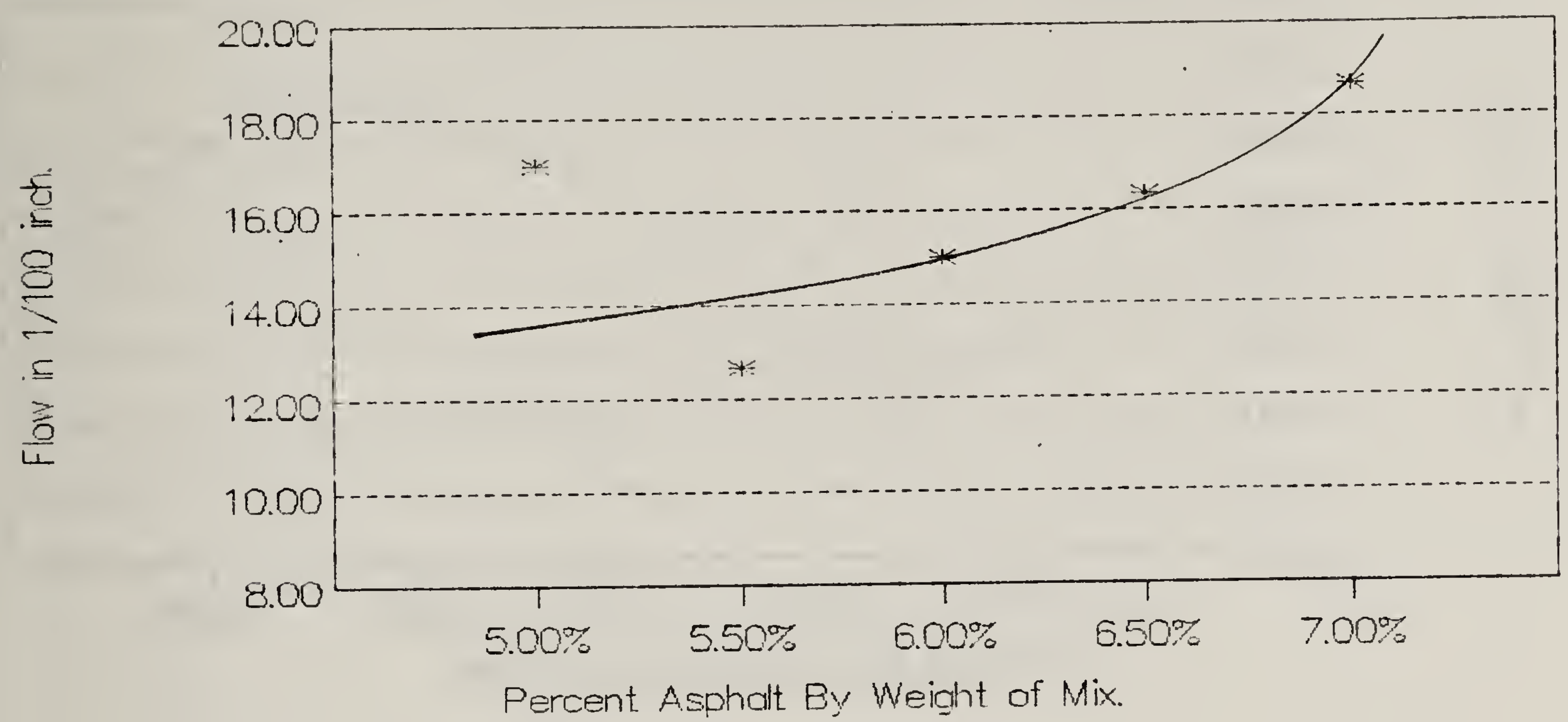
Kraton (4.3%) Mod. Conoco–Unit Weight

Split Aggregates Case III–50 Blows



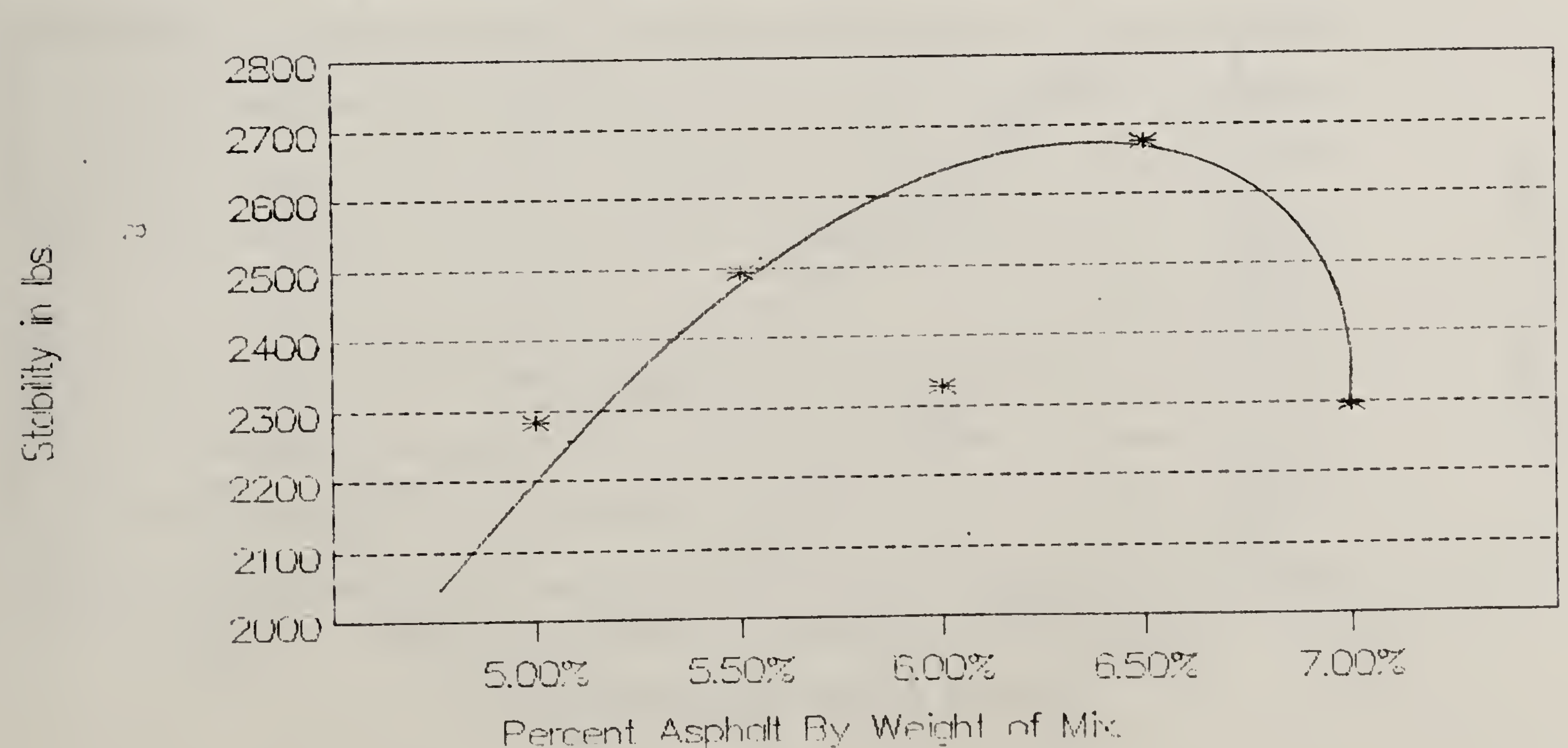
Kraton (6%) Mod. Conoco–Flow

Split Aggregates Case III–50 Blows



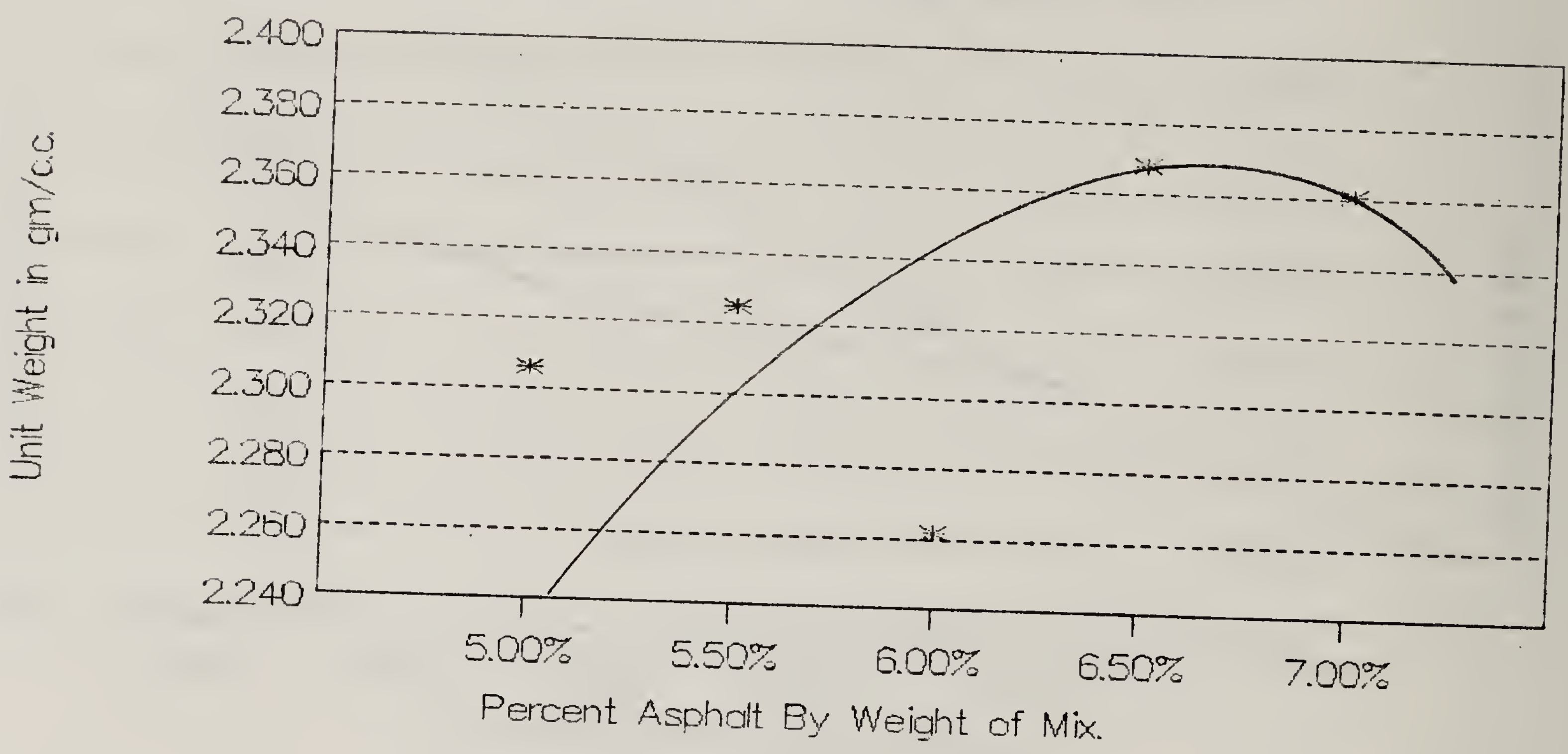
Kraton (6%) Mod. Conoco–Stability

Split Aggregates Case III–50 Blows



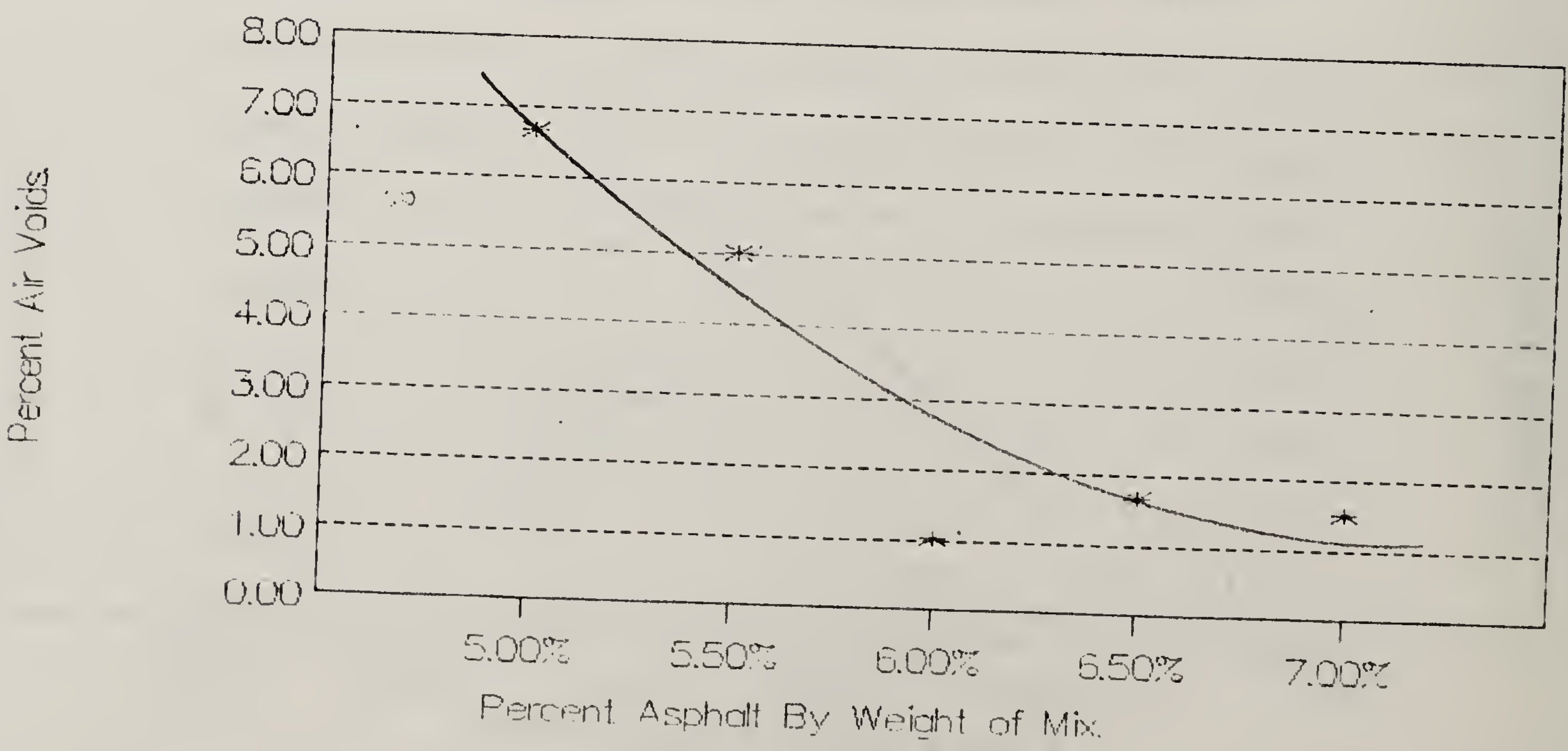
Kraton (6%) Mod. Conoco–Unit Weight

Split Aggregates Case III–50 Blows



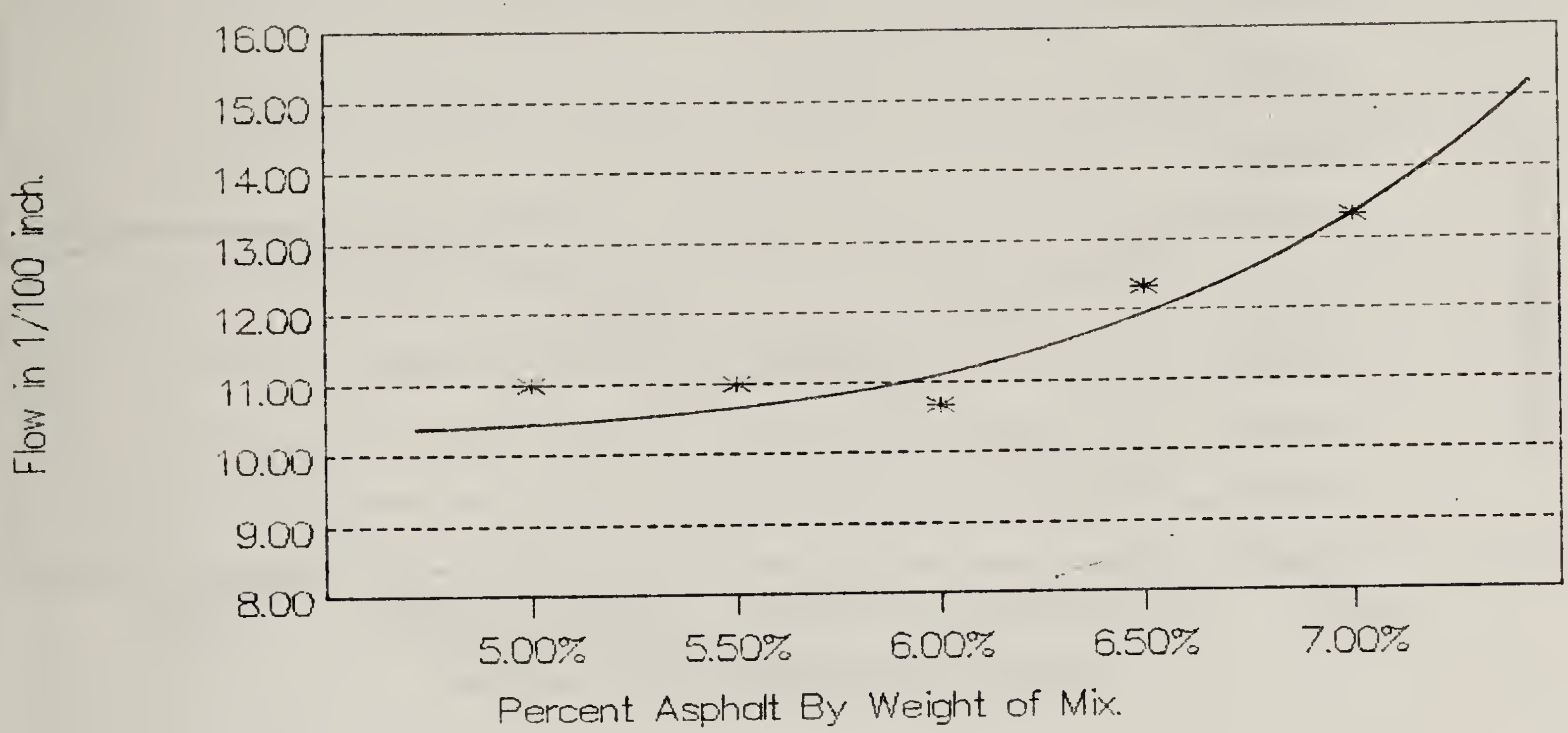
Kraton (6%) Mod. Conoco–Air Voids

Split Aggregates Case III–50 Blows



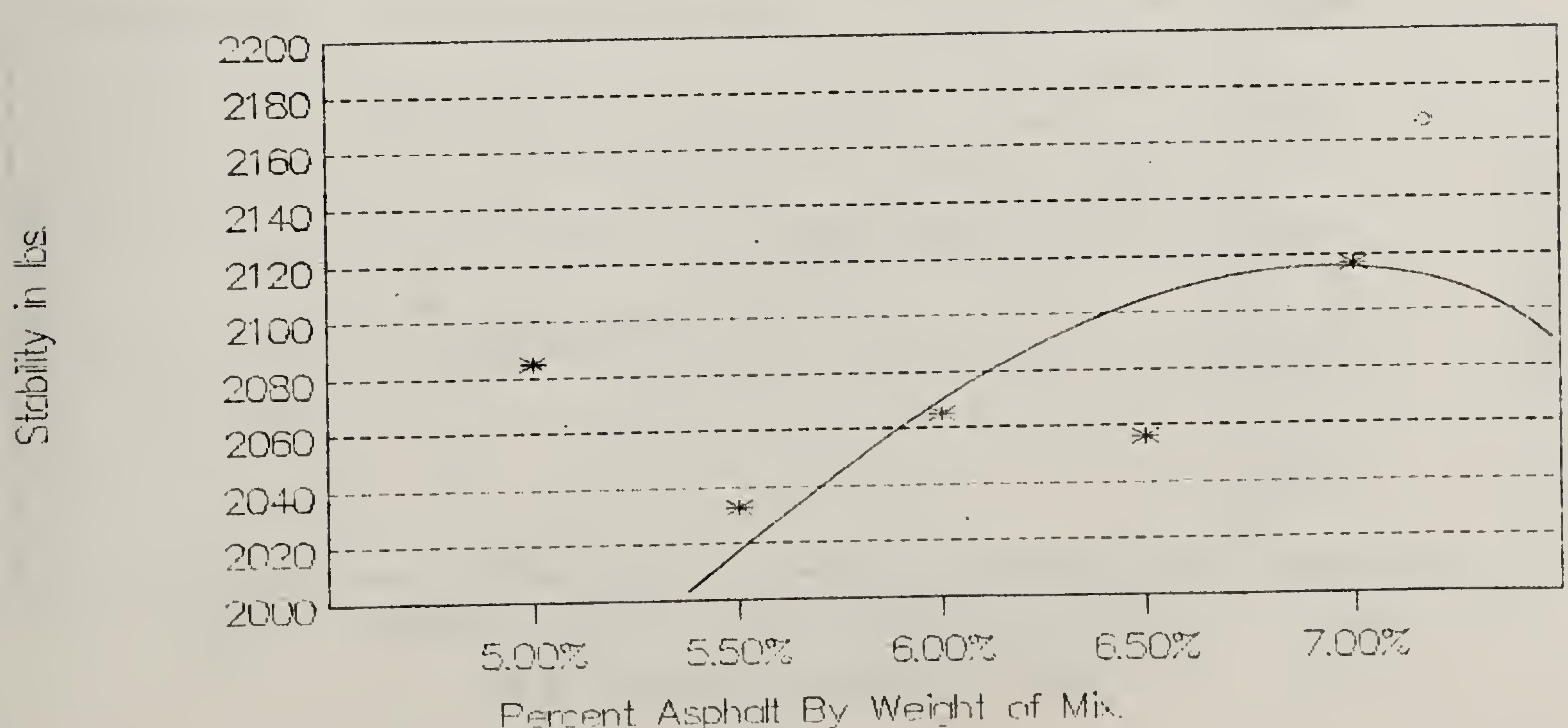
Polybilt Mod. Conoco–Flow

Split Aggregates Case III–50 Blows



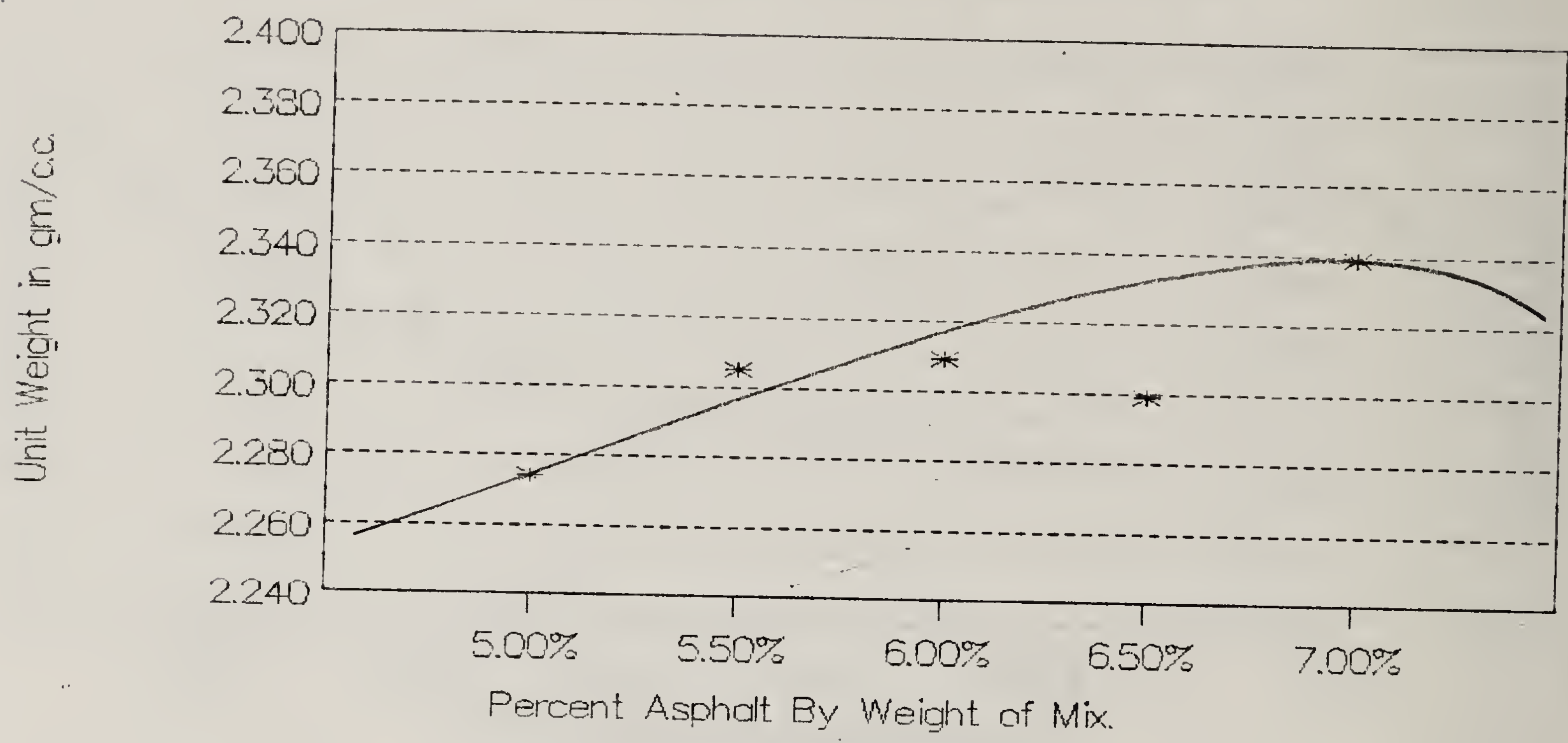
Polybilt Mod. Conoco–Stability

Split Aggregates Case III–50 Blows



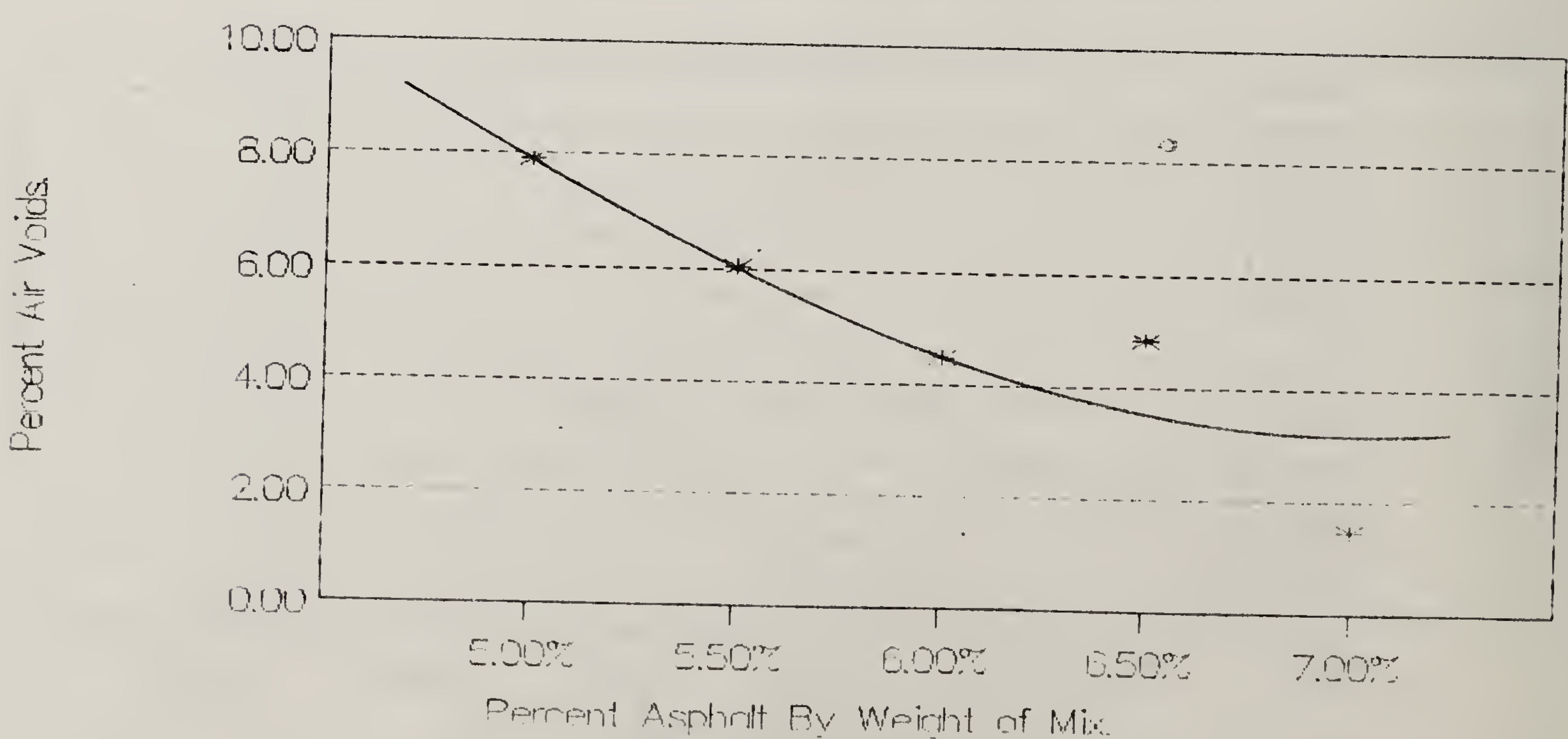
Polybilt Mod. Conoco–Unit Weight

Split Aggregates Case III–50 Blows



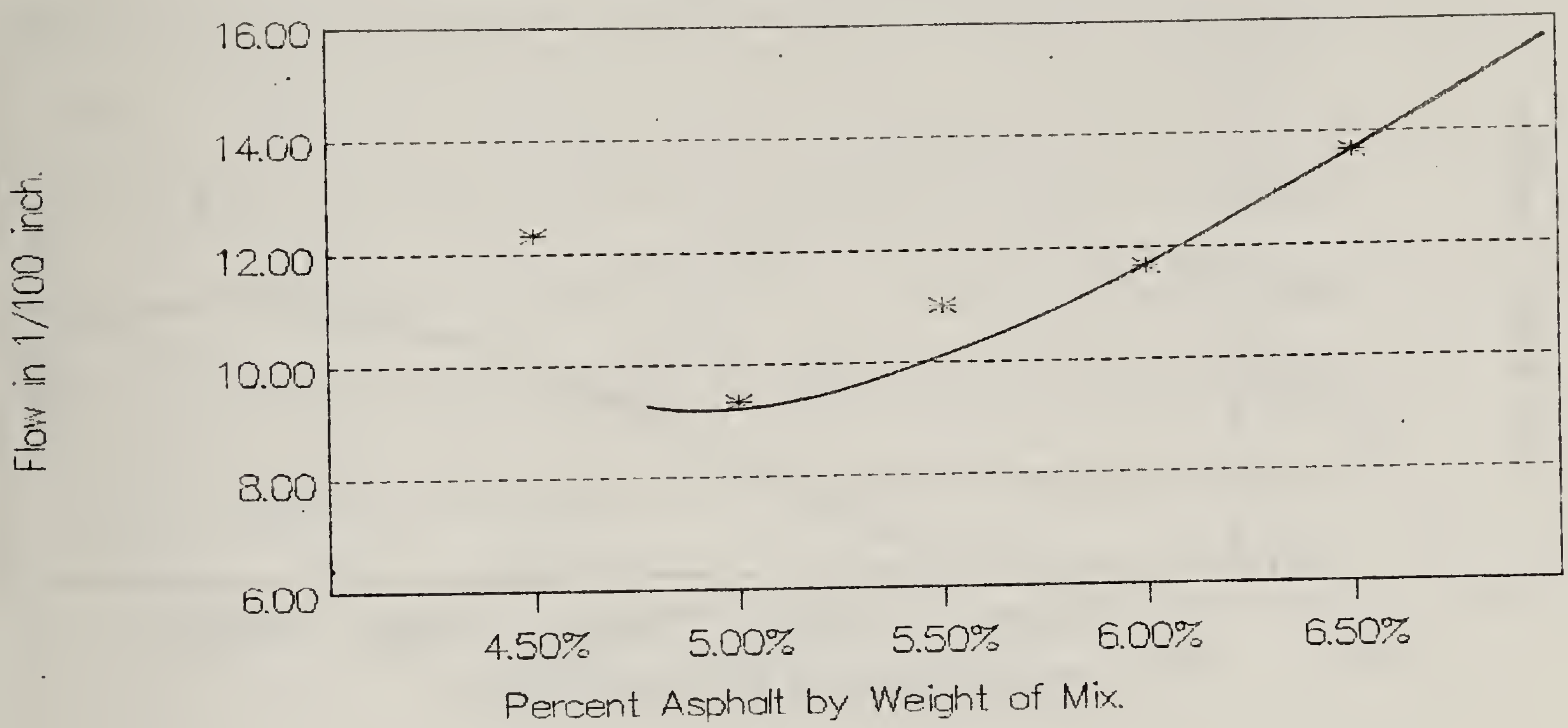
Polybilt Mod. Conoco–Air Voids

Split Aggregates Case III–50 Blows



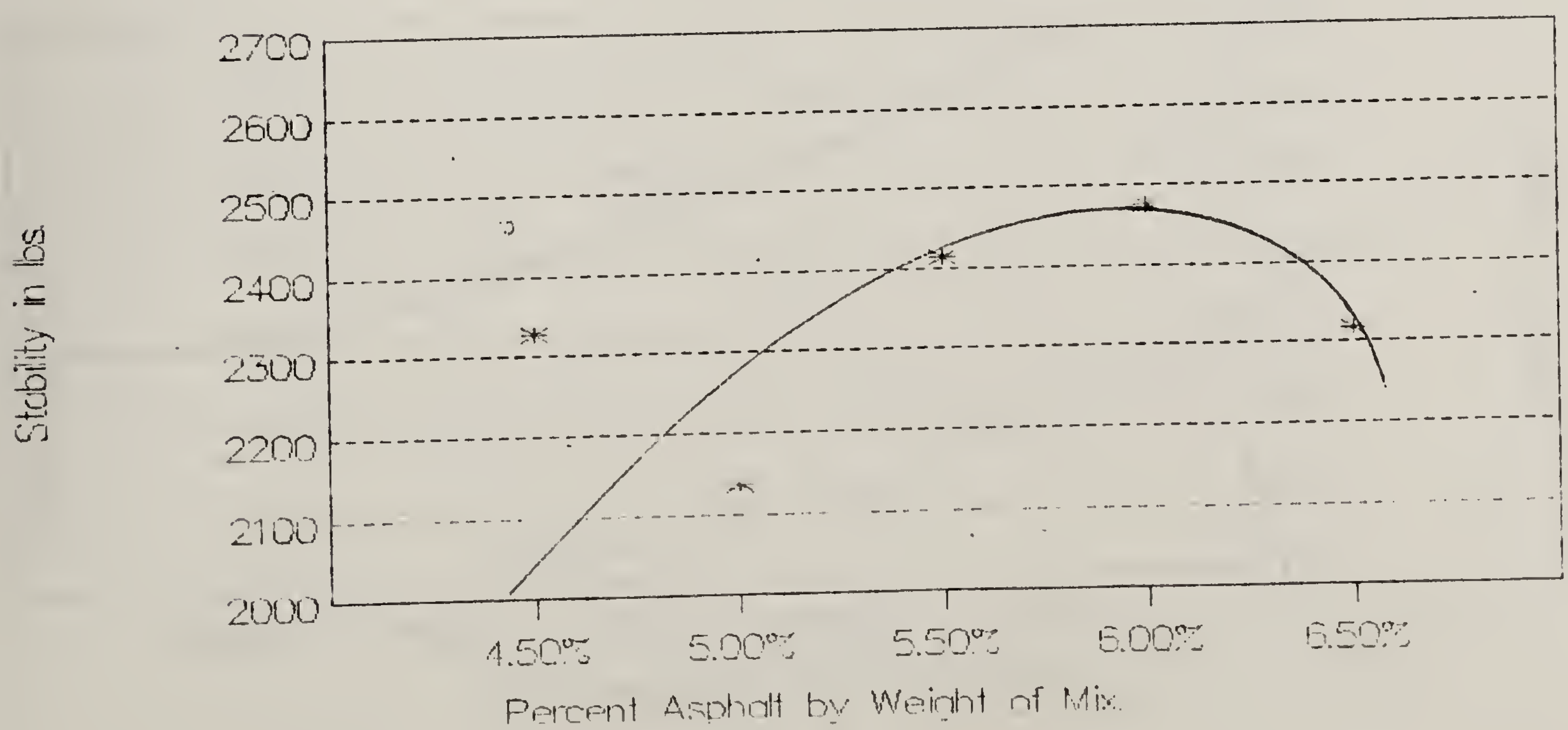
Unmodified Cenex-Flow

Split Aggregates-75 Blows



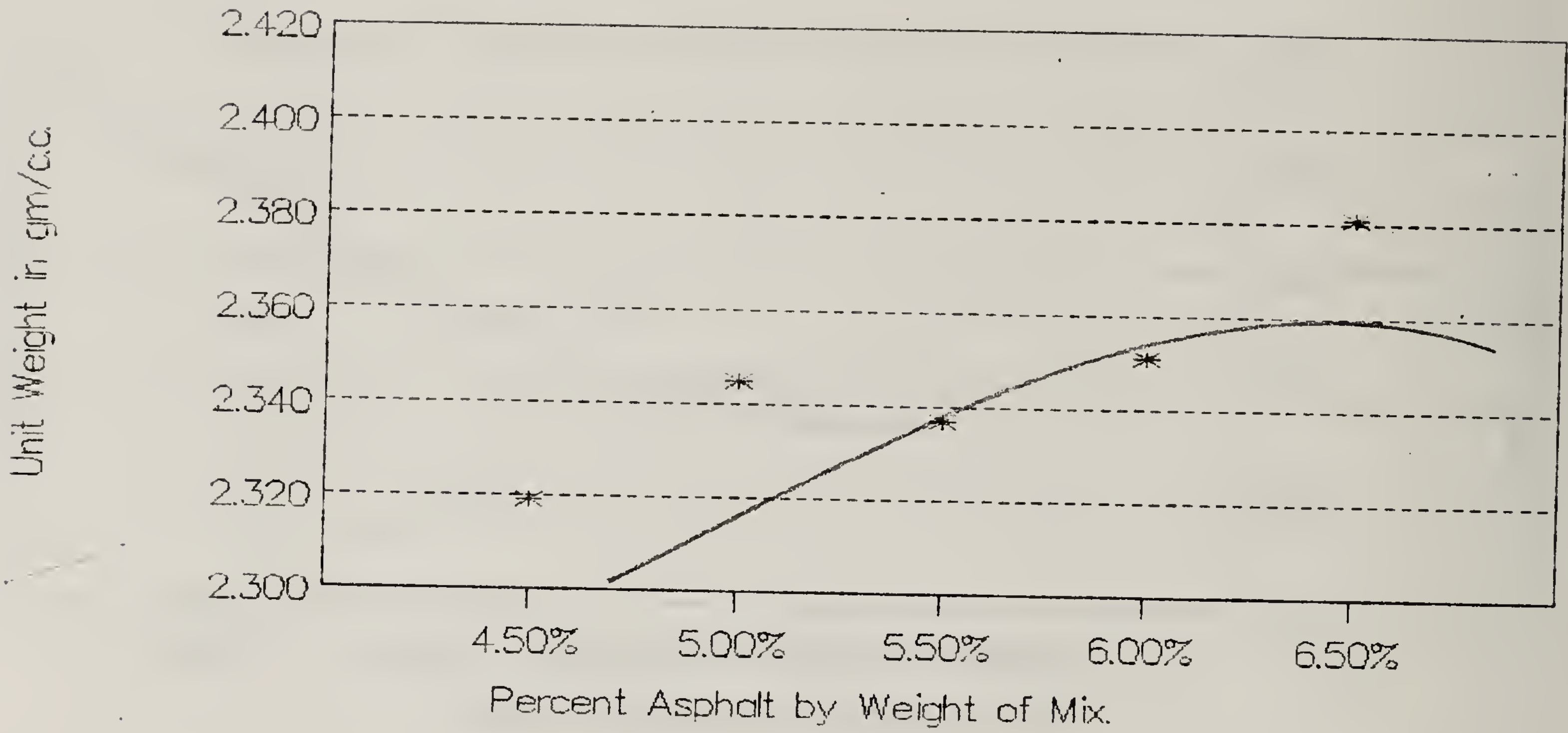
Unmodified Cenex-Stability

Split Aggregates-75 Blows



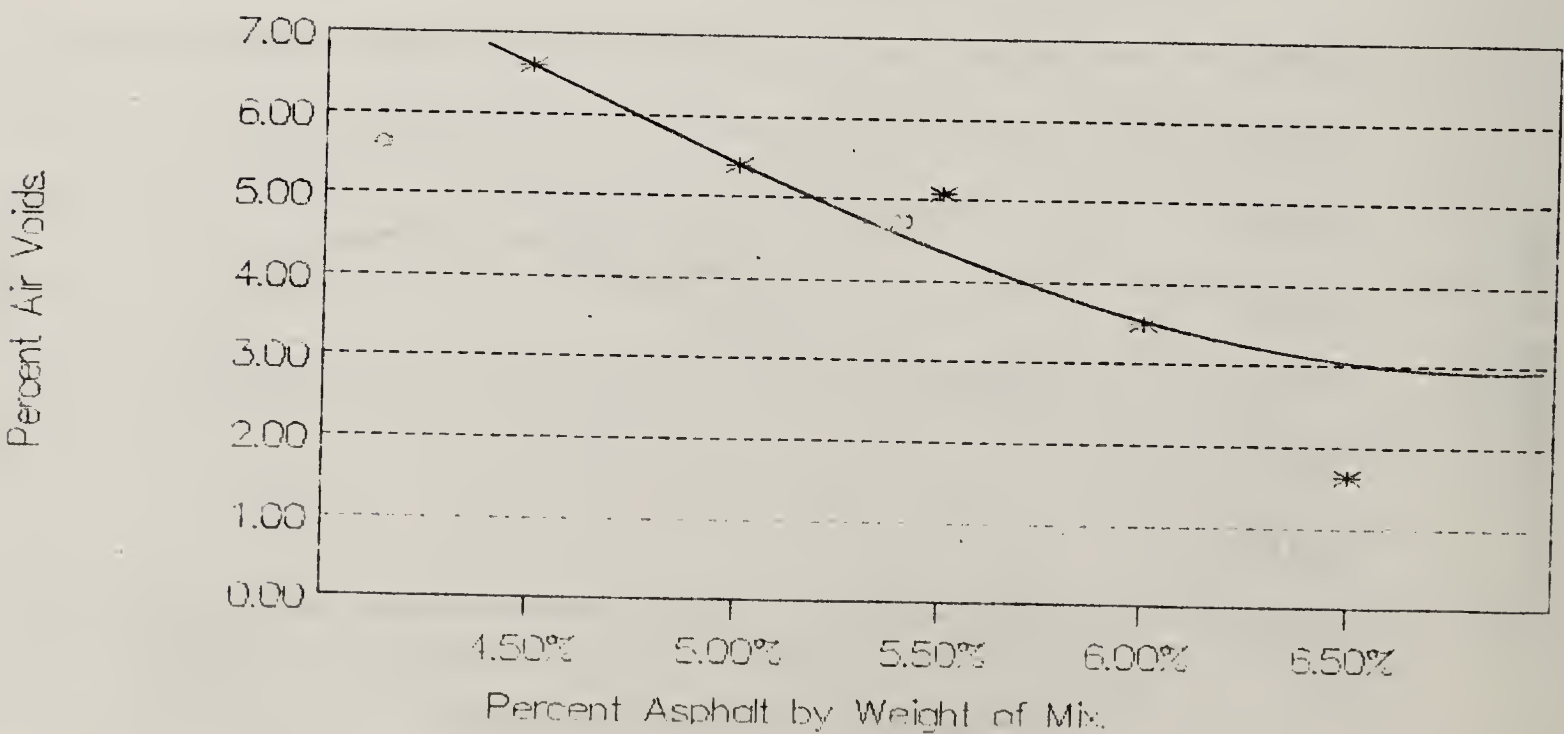
Unmodified Cenex–Unit Weight

Split Aggregates–75 Blows



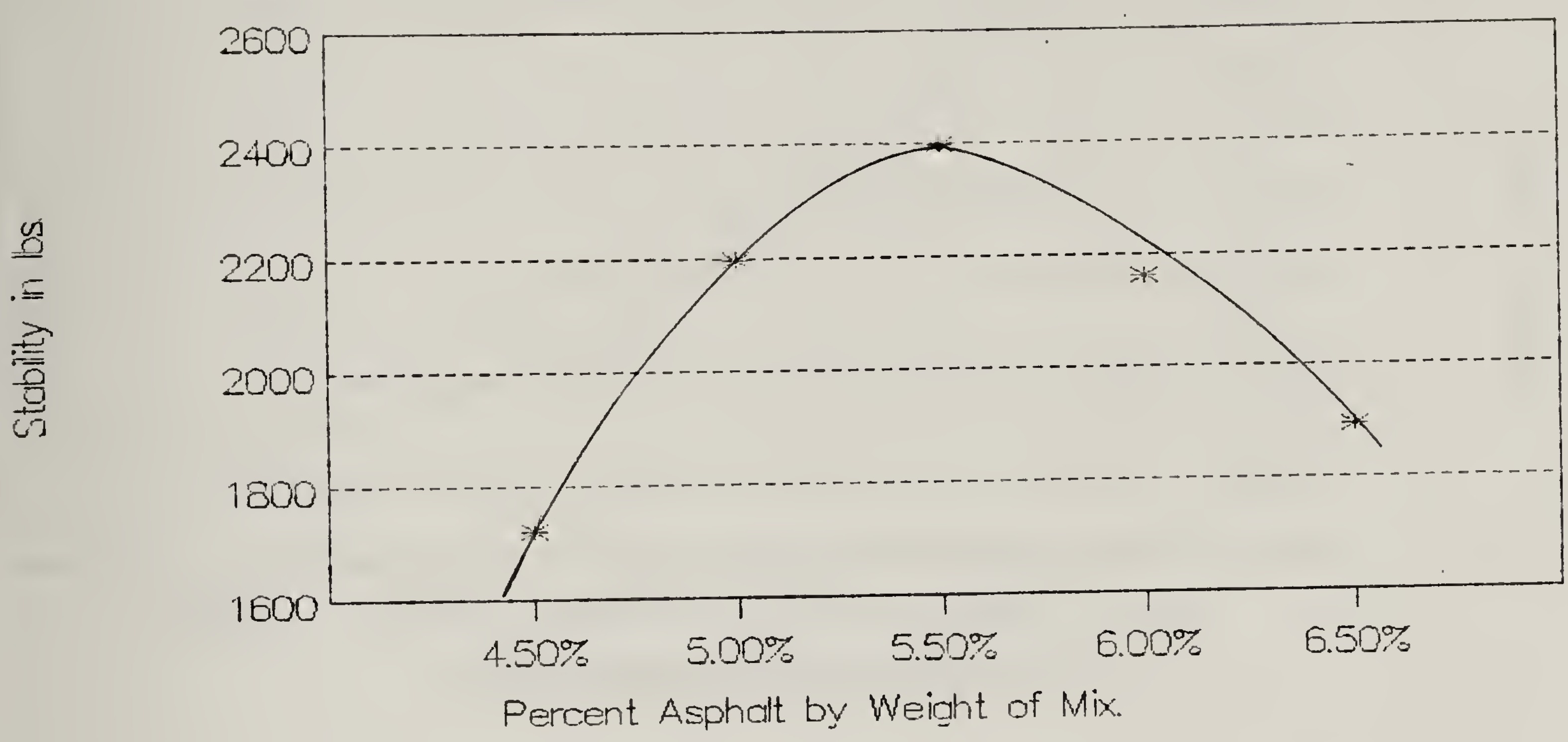
Unmodified Cenex–Percent Air Voids.

Split Aggregates–75 Blows



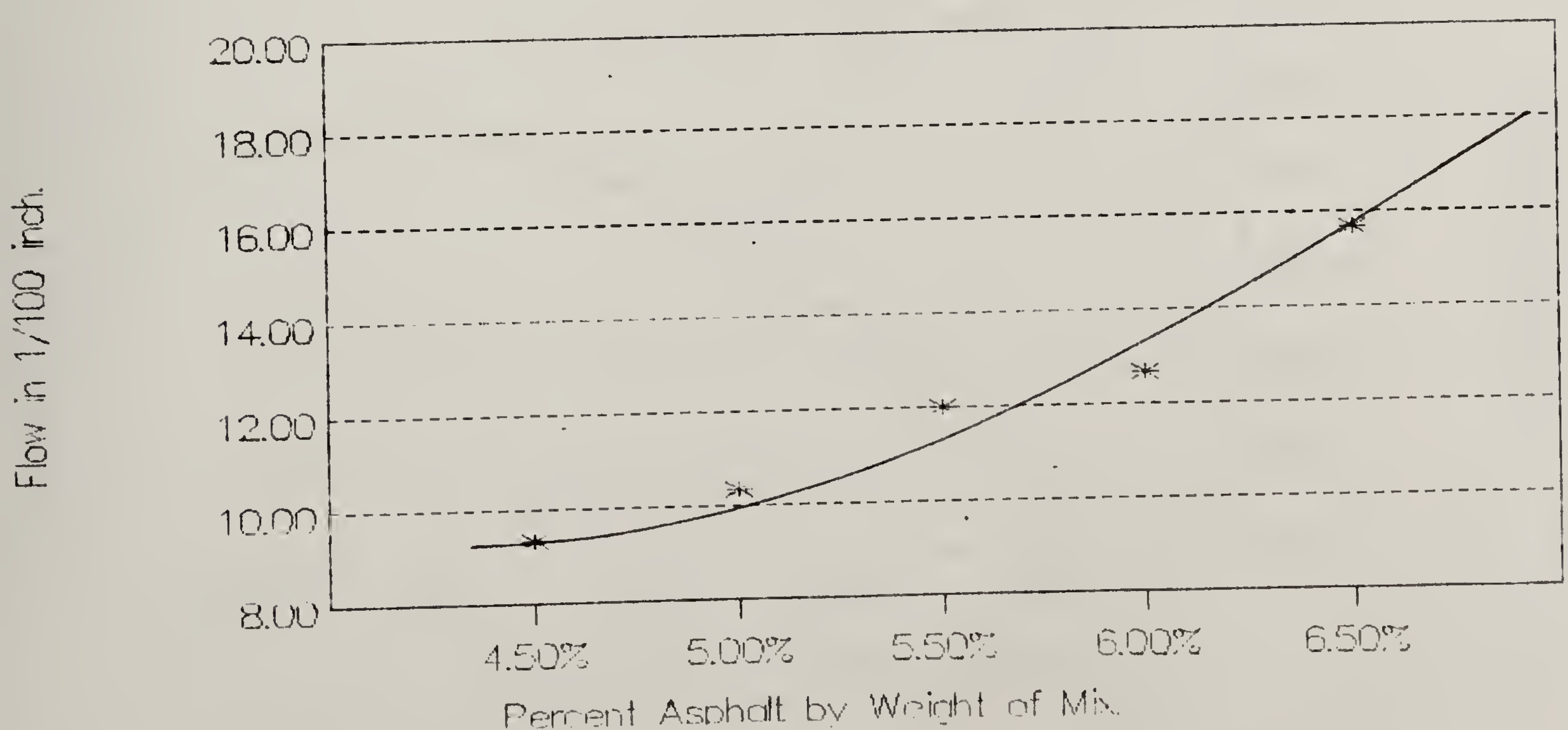
Unmodified Conoco—Stability

Split Aggregates—75 Blows



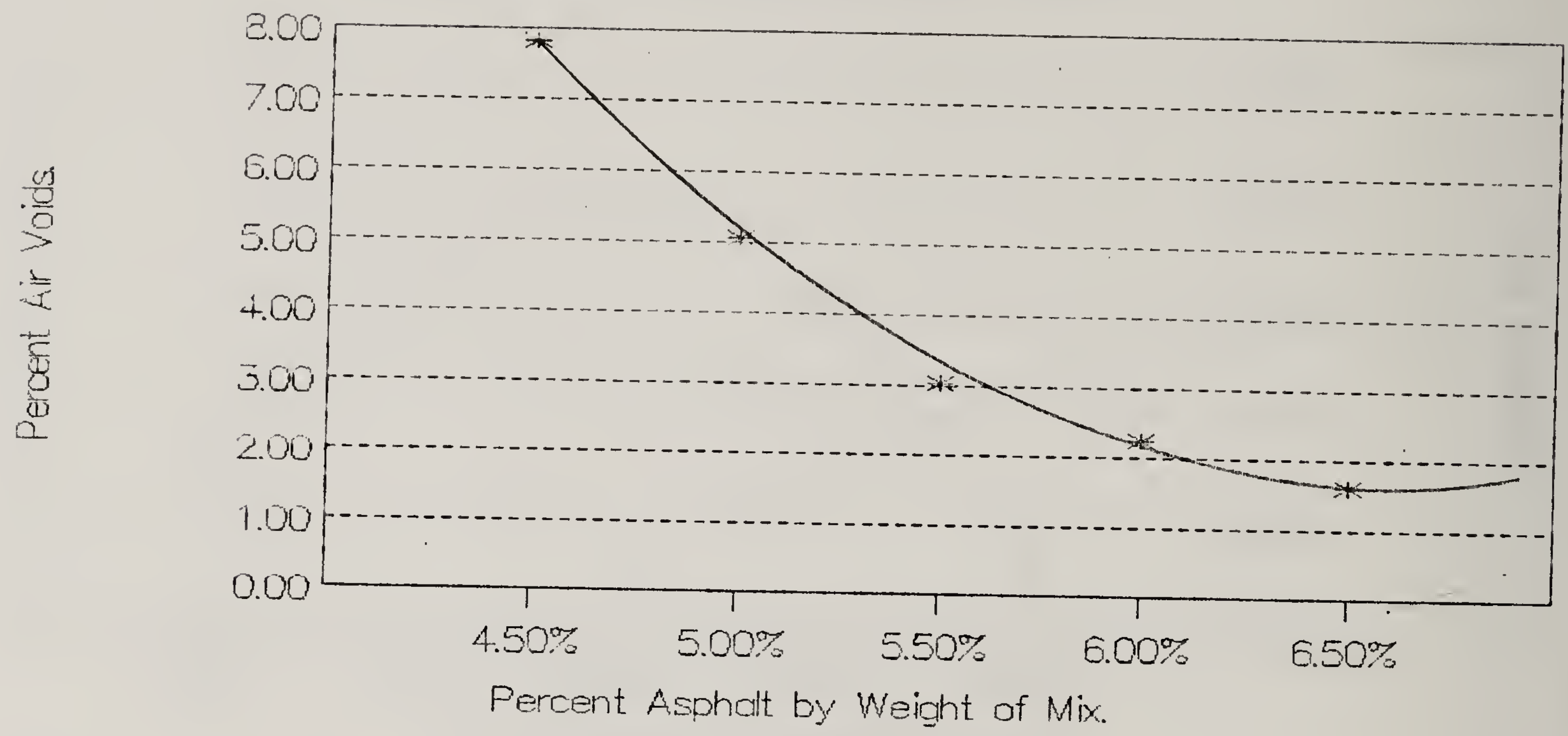
Unmodified Conoco—Flow

Split Aggregates—75 Blows



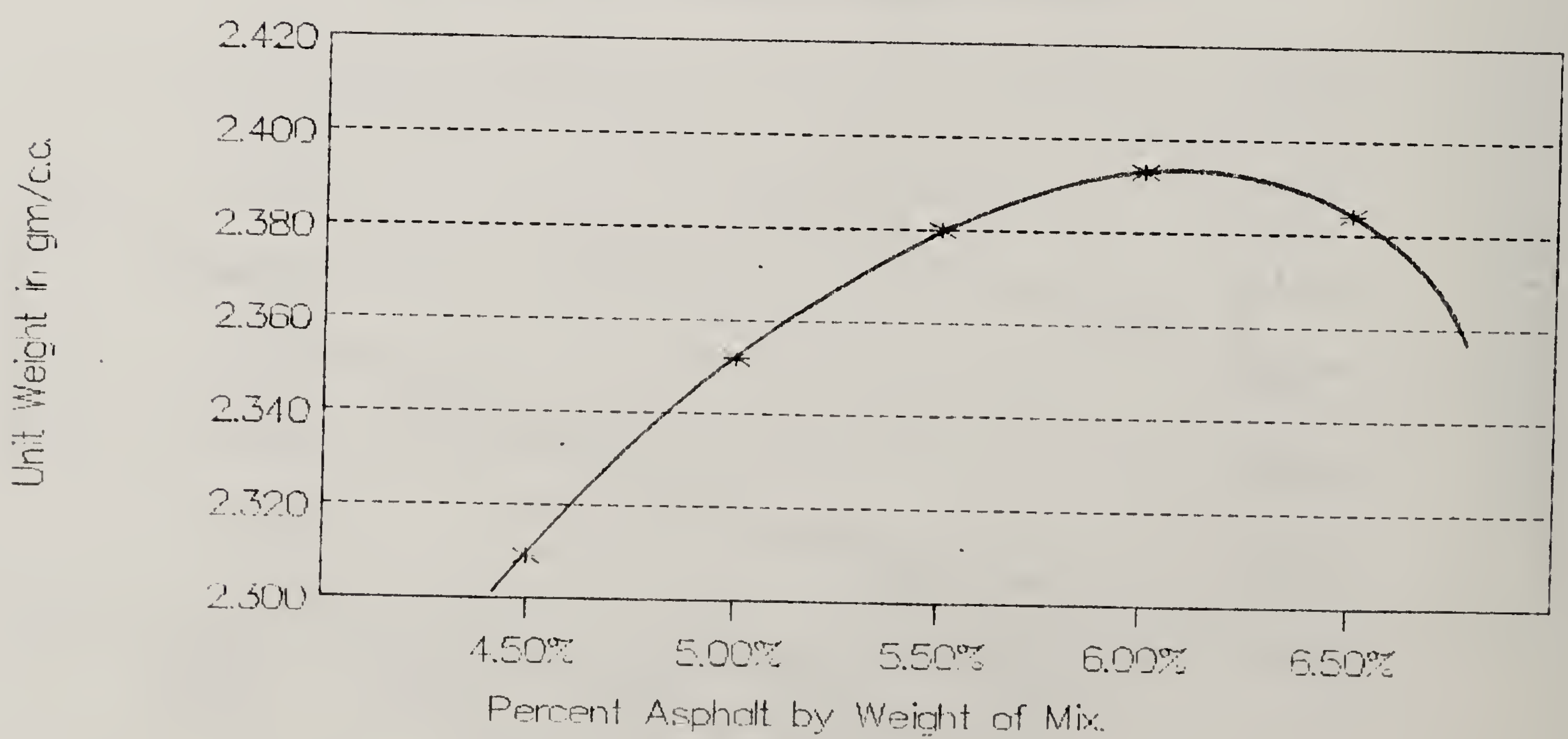
Unmodified Conoco–Percent Air Voids.

Split Aggregates–75 Blows



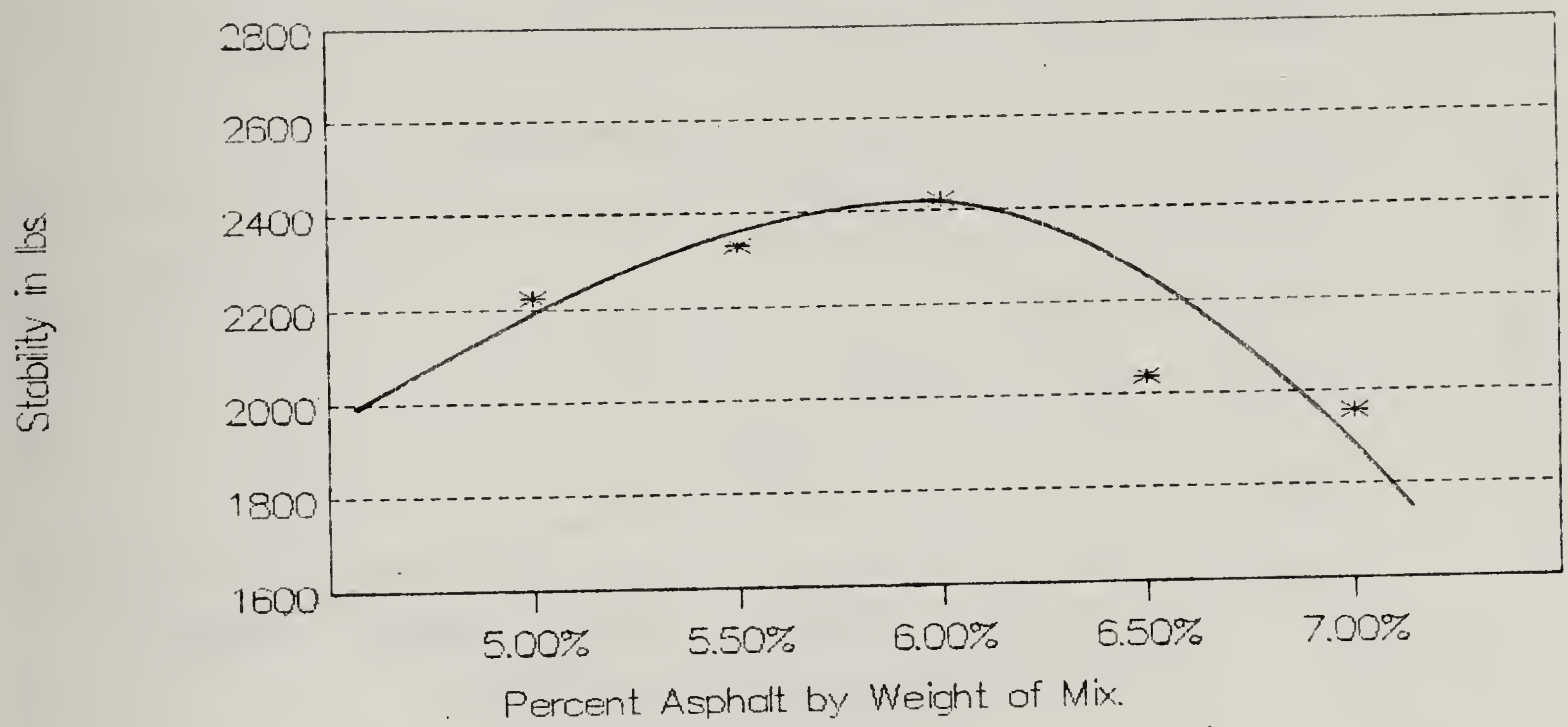
Unmodified Conoco–Unit Weight

Split Aggregates–75 Blows



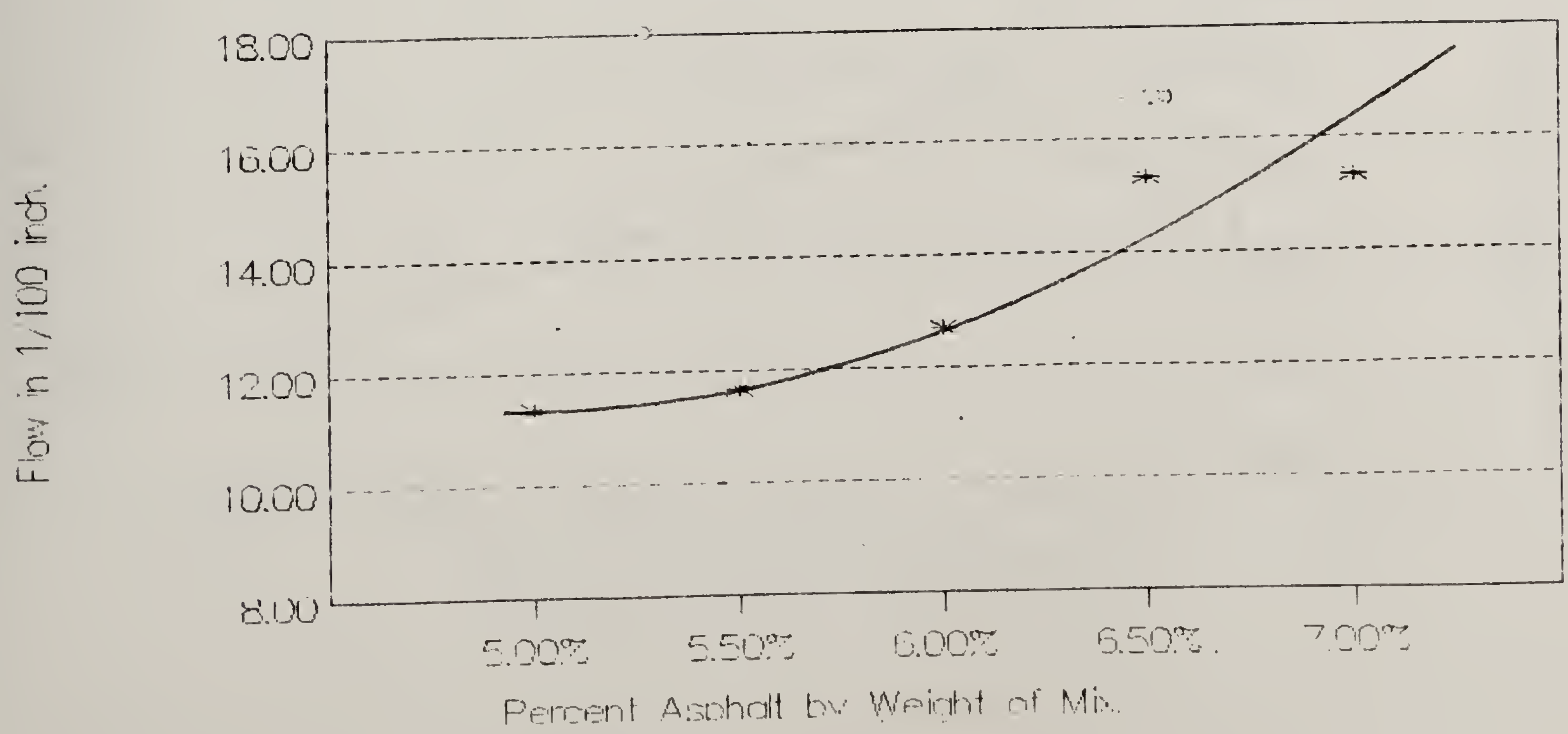
Unmodified Cenex–Stability

Controlled Aggregates



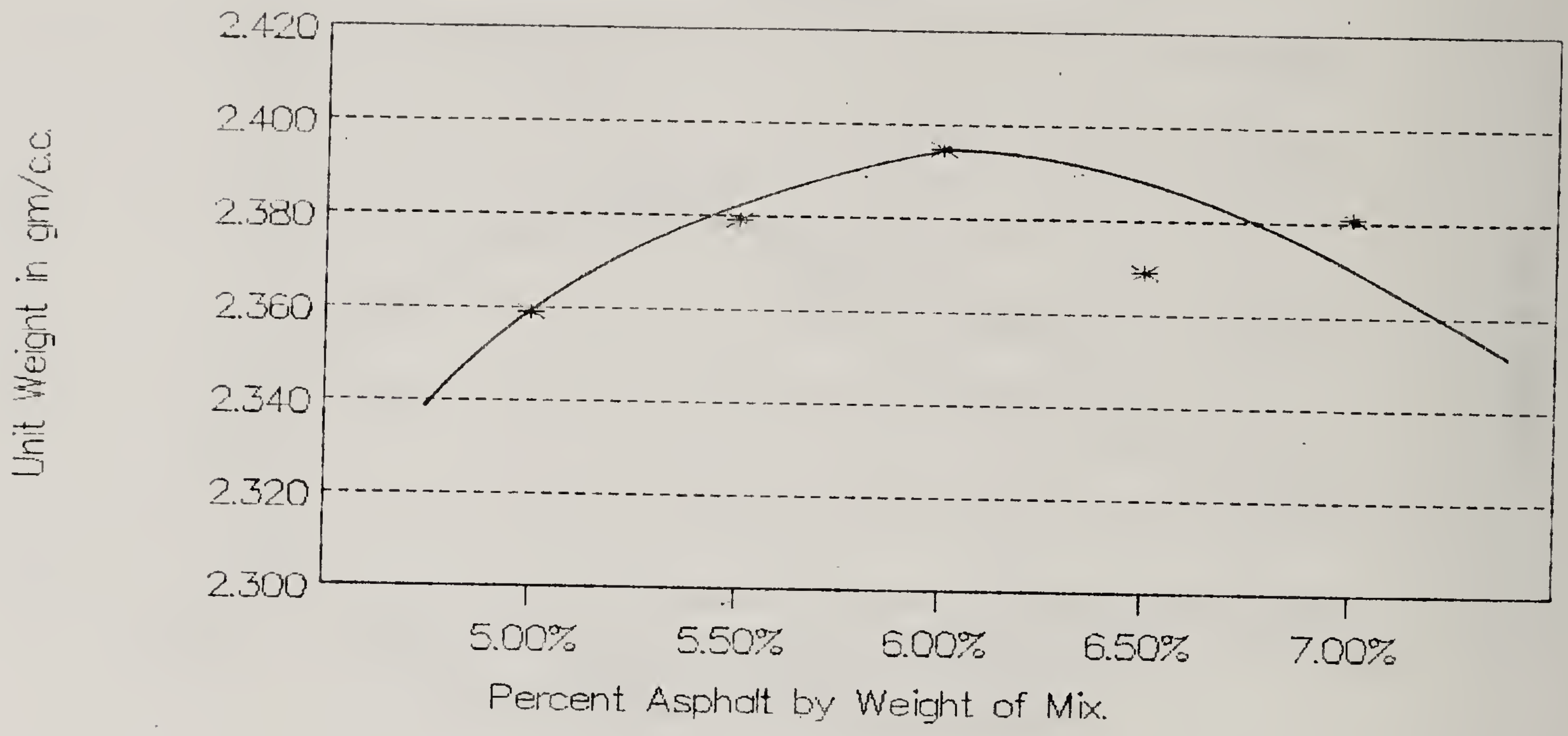
Unmodified Cenex–Flow

Controlled Aggregates



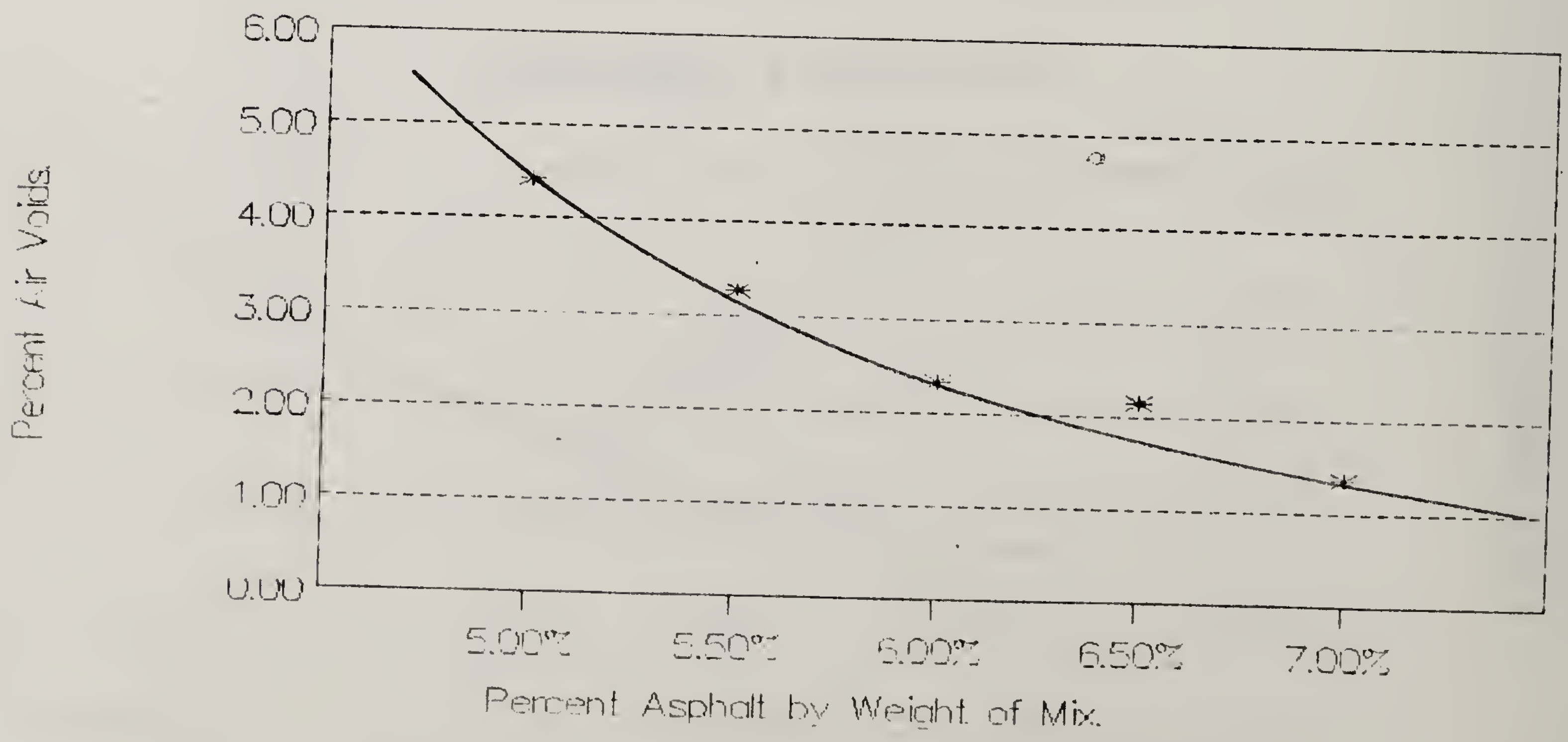
Unmodified Cenex–Unit Weight

Controlled Aggregates



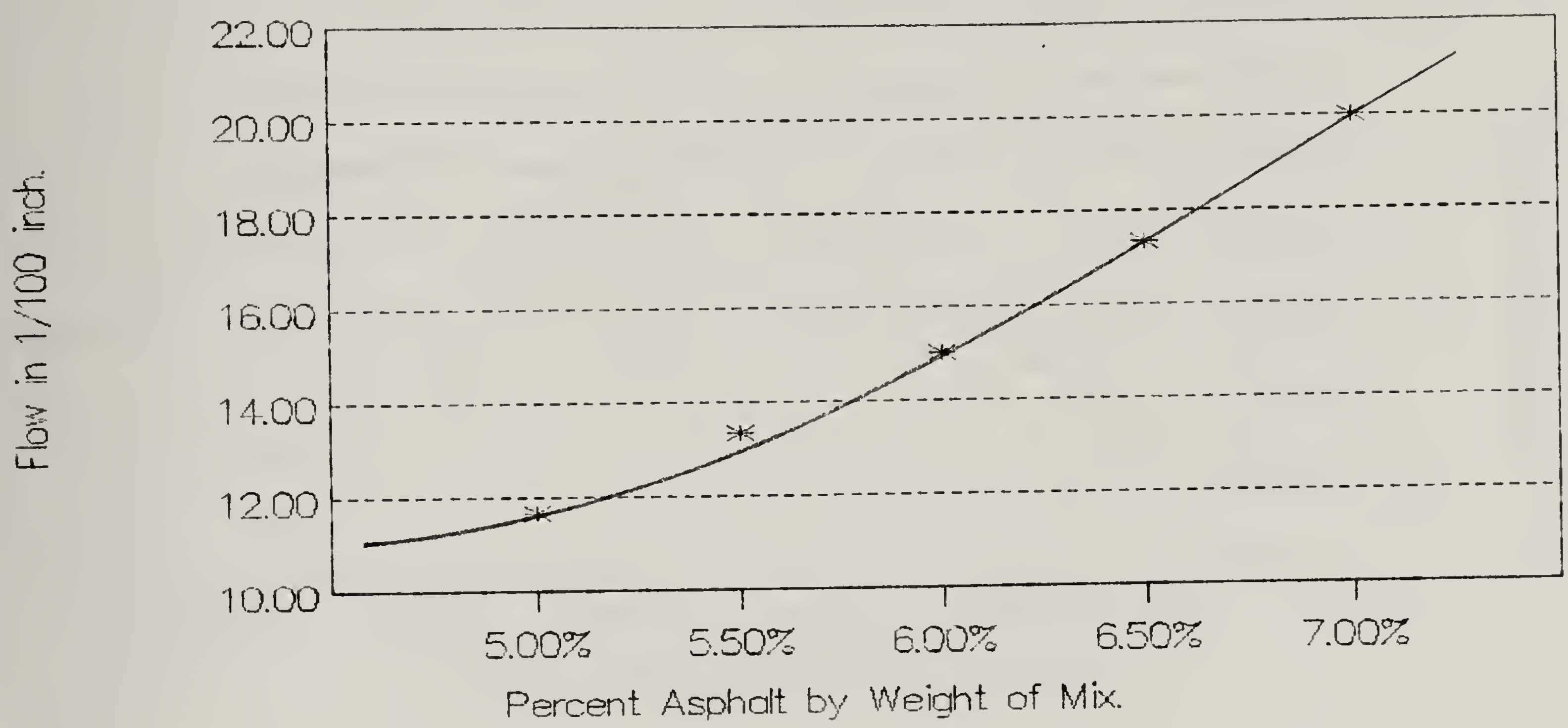
Unmodified Cenex–Percent Air Voids

Controlled Aggregates



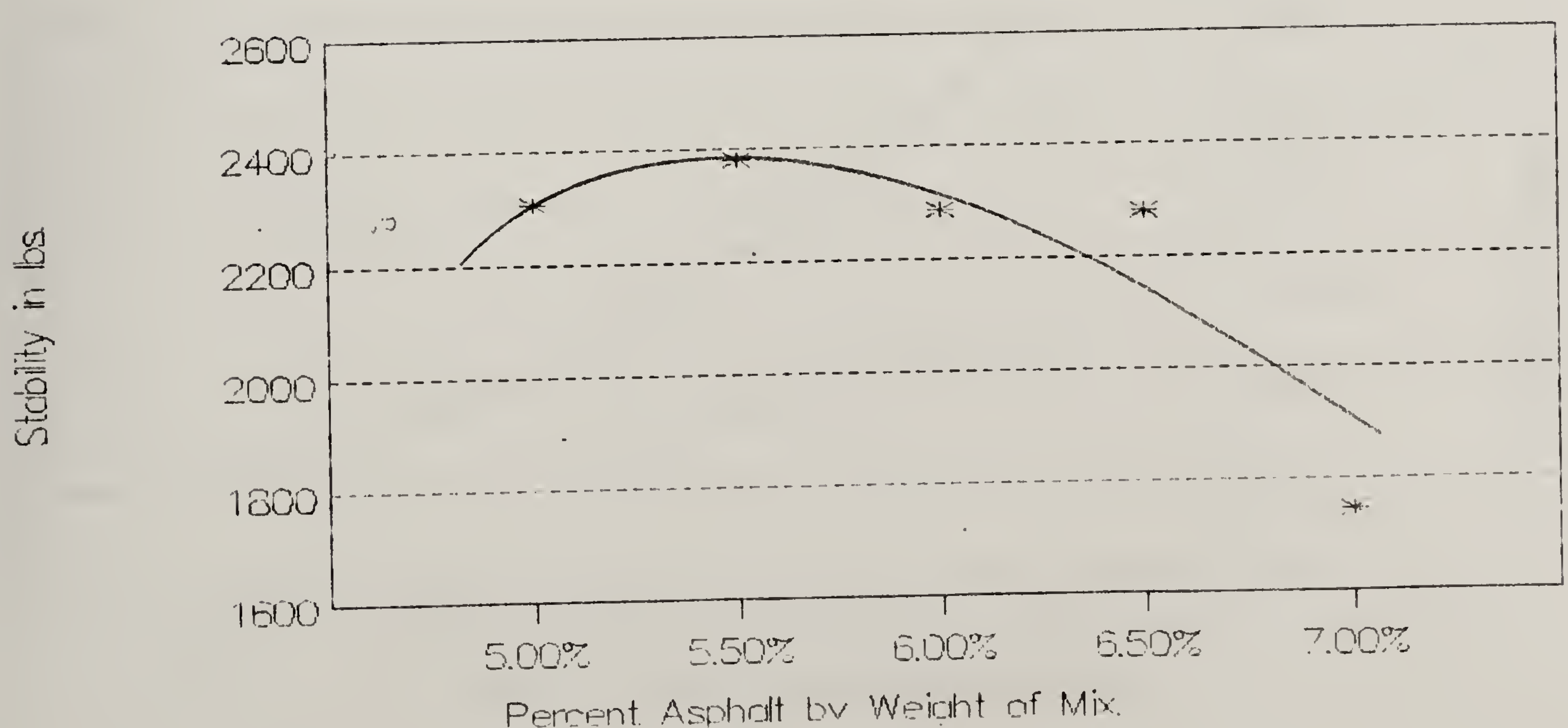
Kraton(6%) Mod. Cenex-Flow

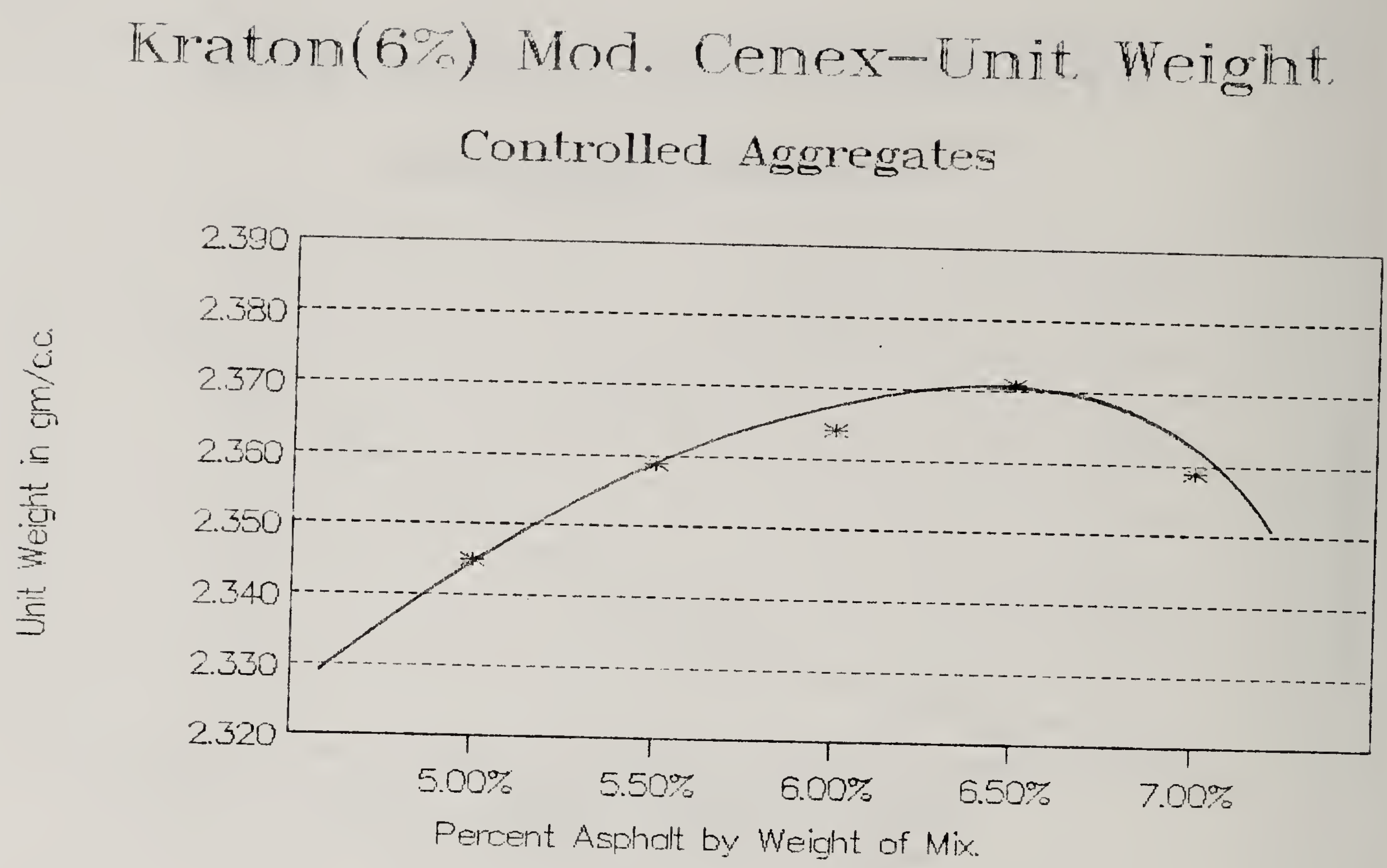
Controlled Aggregates

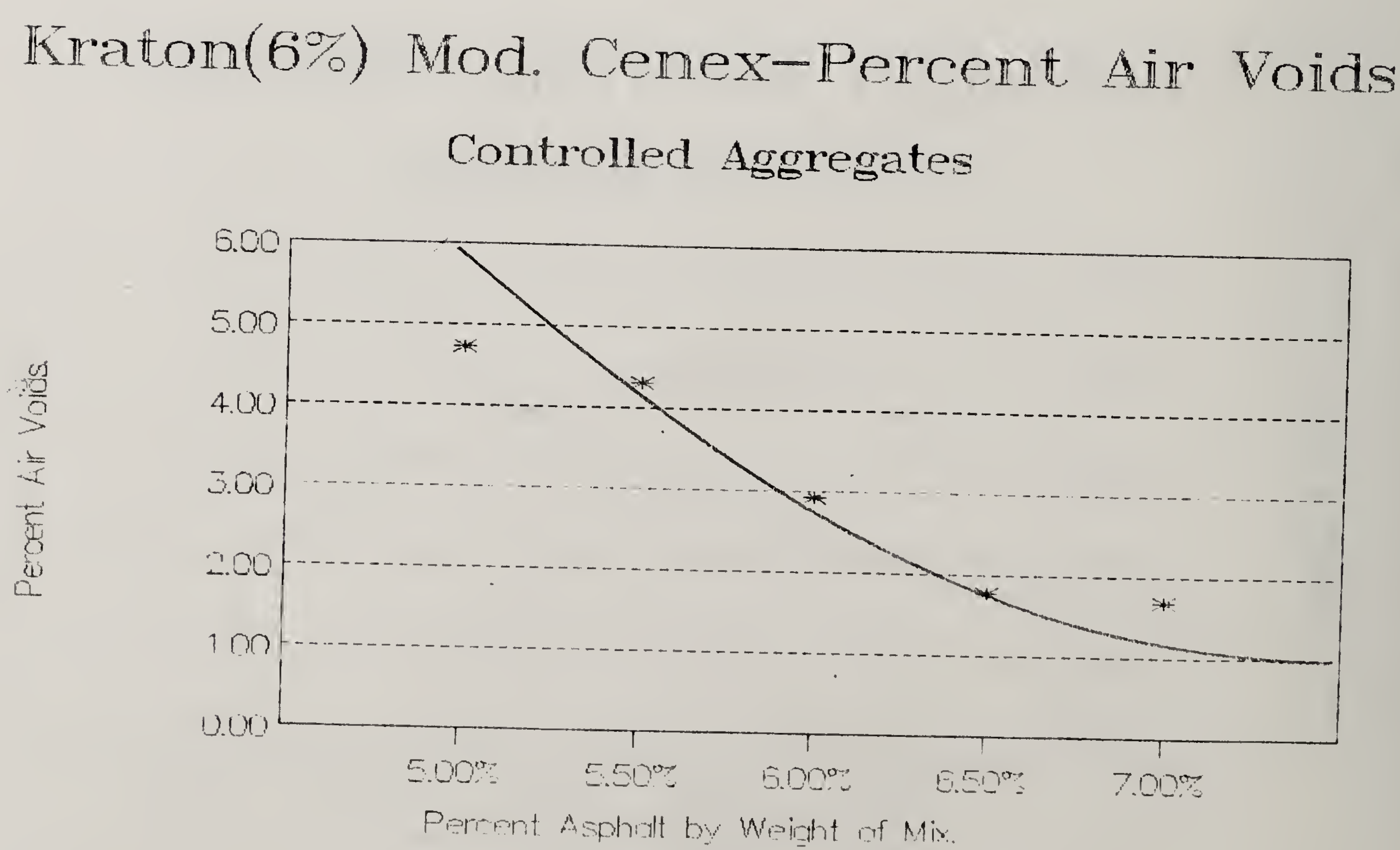


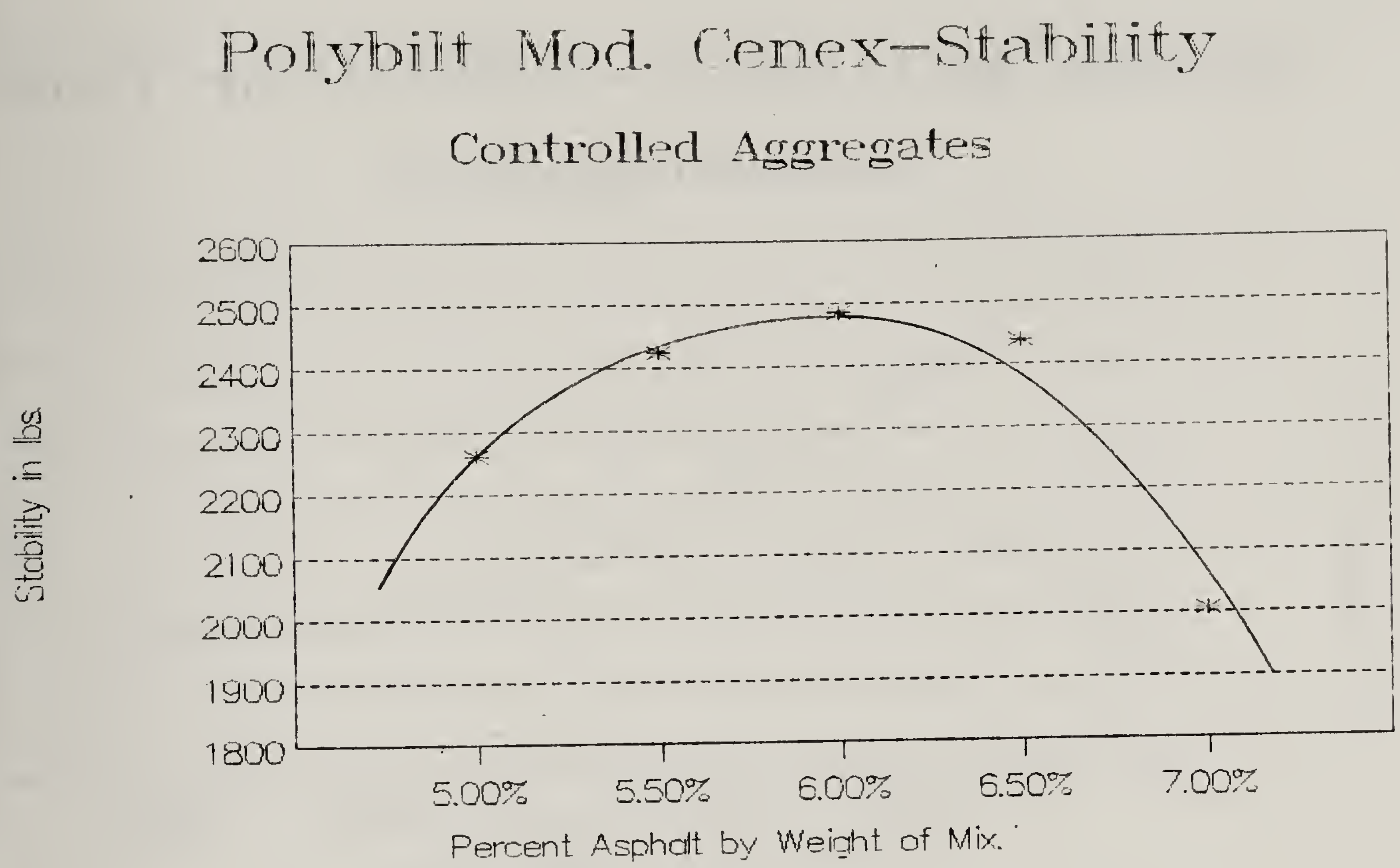
Kraton(6%) Mod. Cenex-Stability

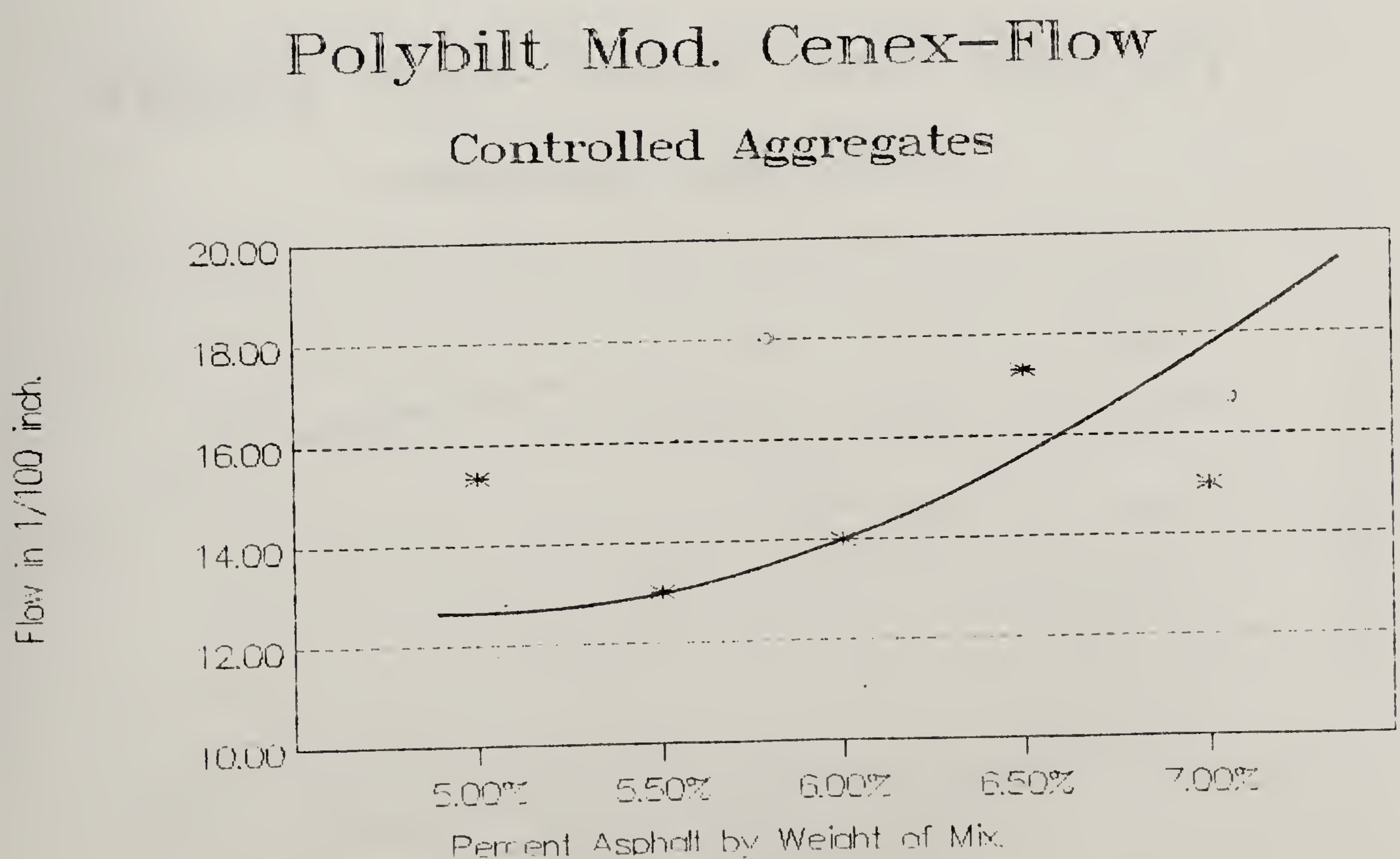
Controlled Aggregates




Kraton(6%) Mod. Cenex–Unit Weight
Controlled Aggregates
Unit Weight in gm/c.c.
2.390
2.380
2.370
2.360
2.350
2.340
2.330
2.320
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.

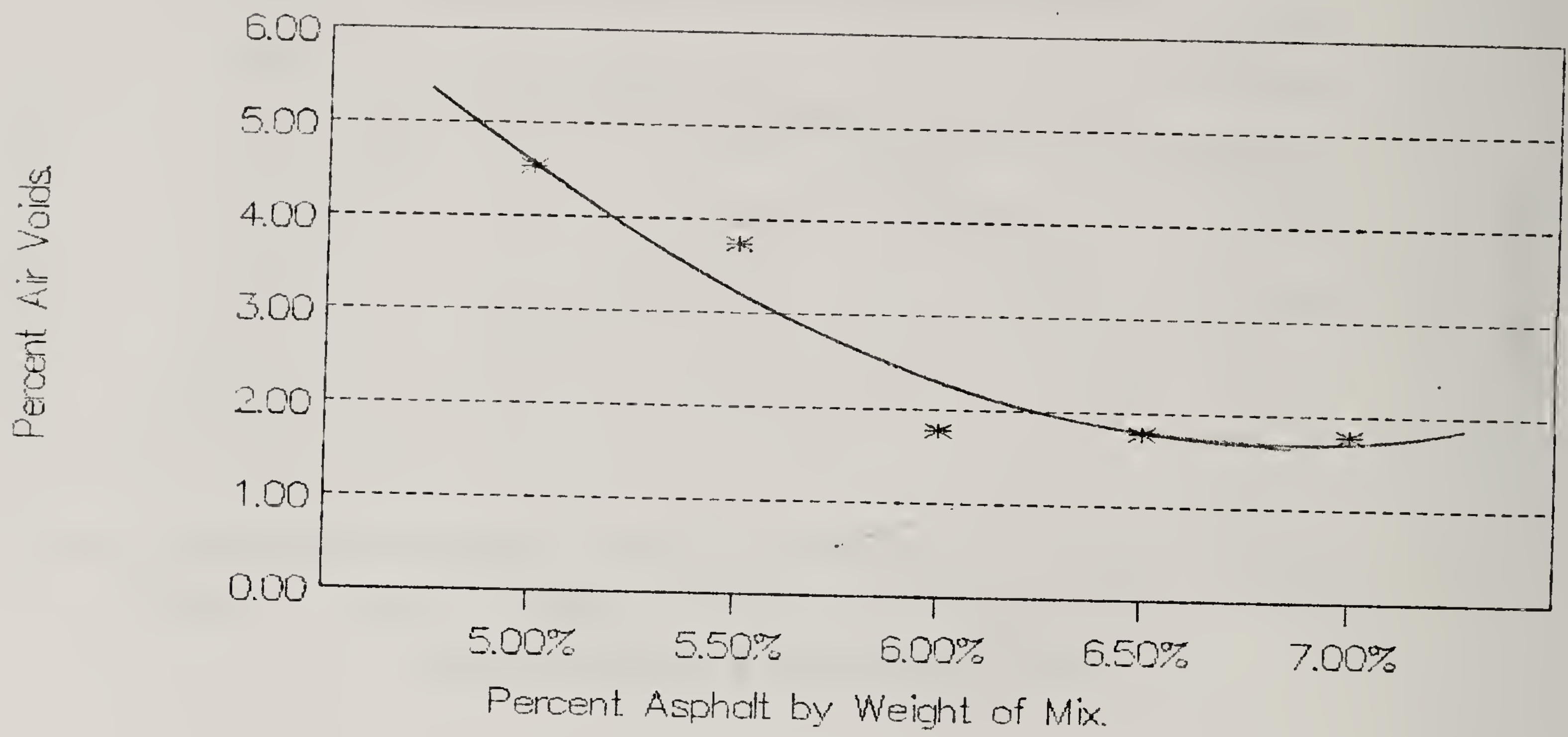

Kraton(6%) Mod. Cenex–Percent Air Voids
Controlled Aggregates
Percent Air Voids
6.00
5.00
4.00
3.00
2.00
1.00
0.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.


Polybilt Mod. Cenex-Stability
Controlled Aggregates
Stability in lbs.
2600
2500
2400
2300
2200
2100
2000
1900
1800
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.


Polybilt Mod. Cenex-Flow
Controlled Aggregates
Flow in 1/100 inch.
20.00
18.00
16.00
14.00
12.00
10.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.

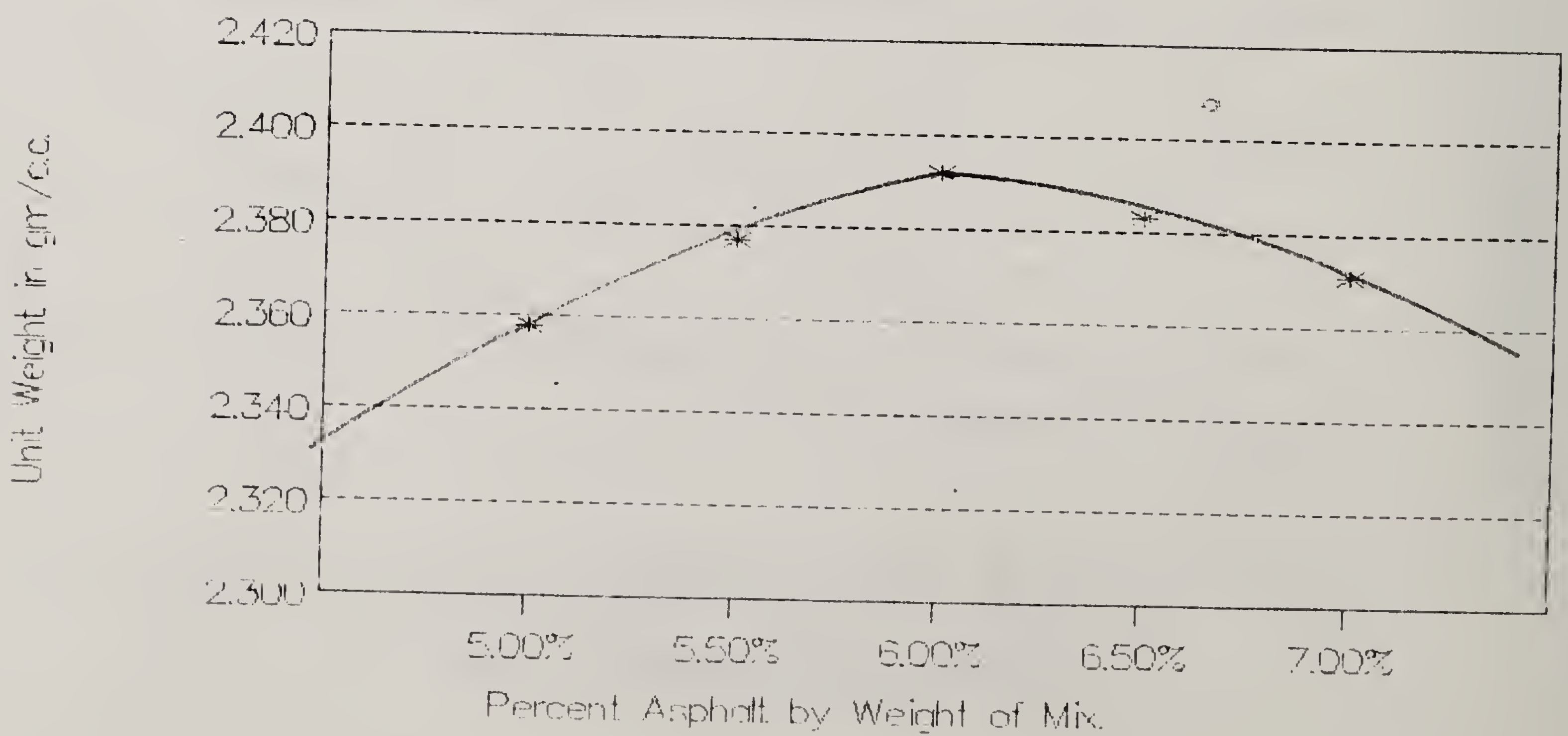
Polybilt Mod. Cenex–Percent Air Voids

Controlled Aggregates



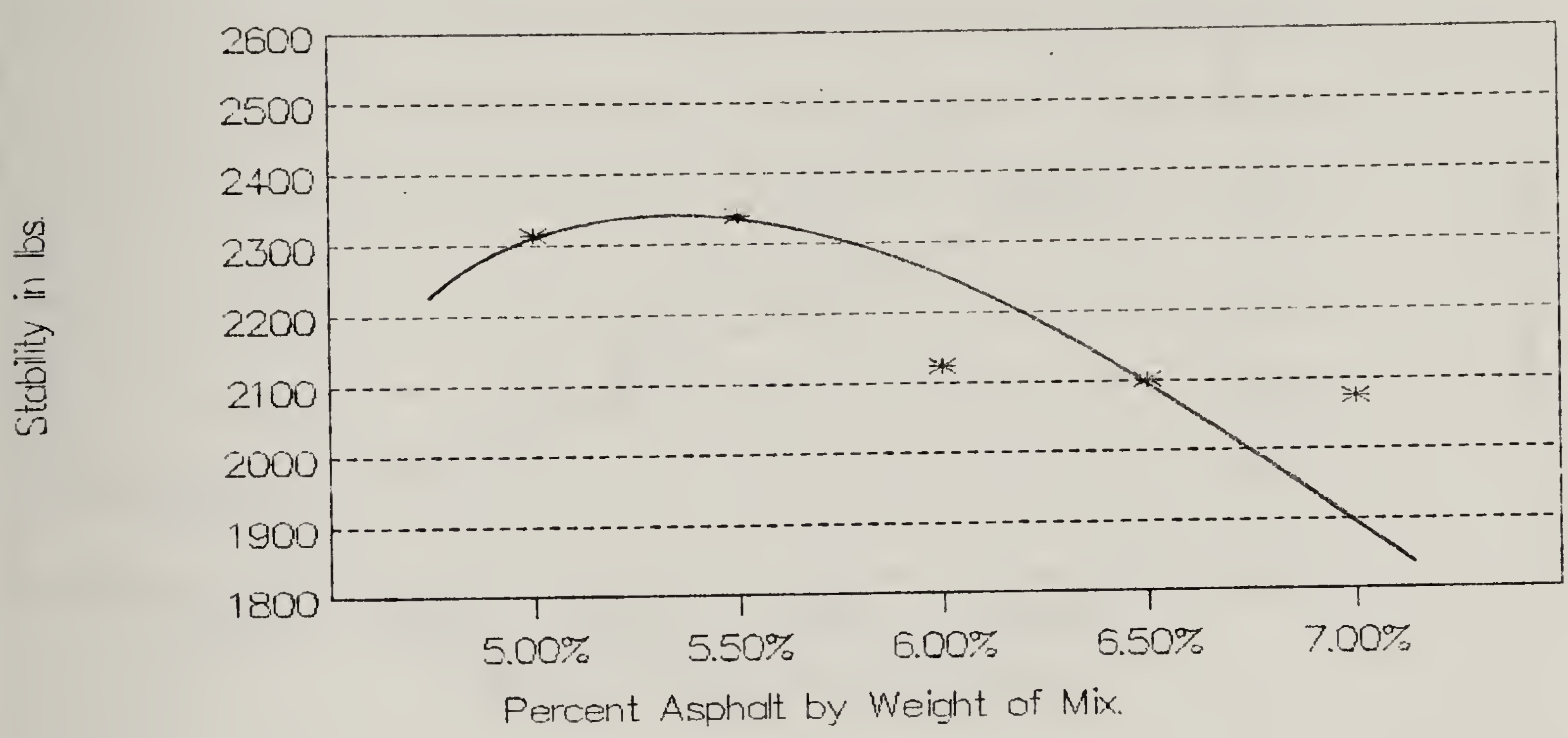
Polybilt Mod. Cenex–Unit Weight

Controlled Aggregates



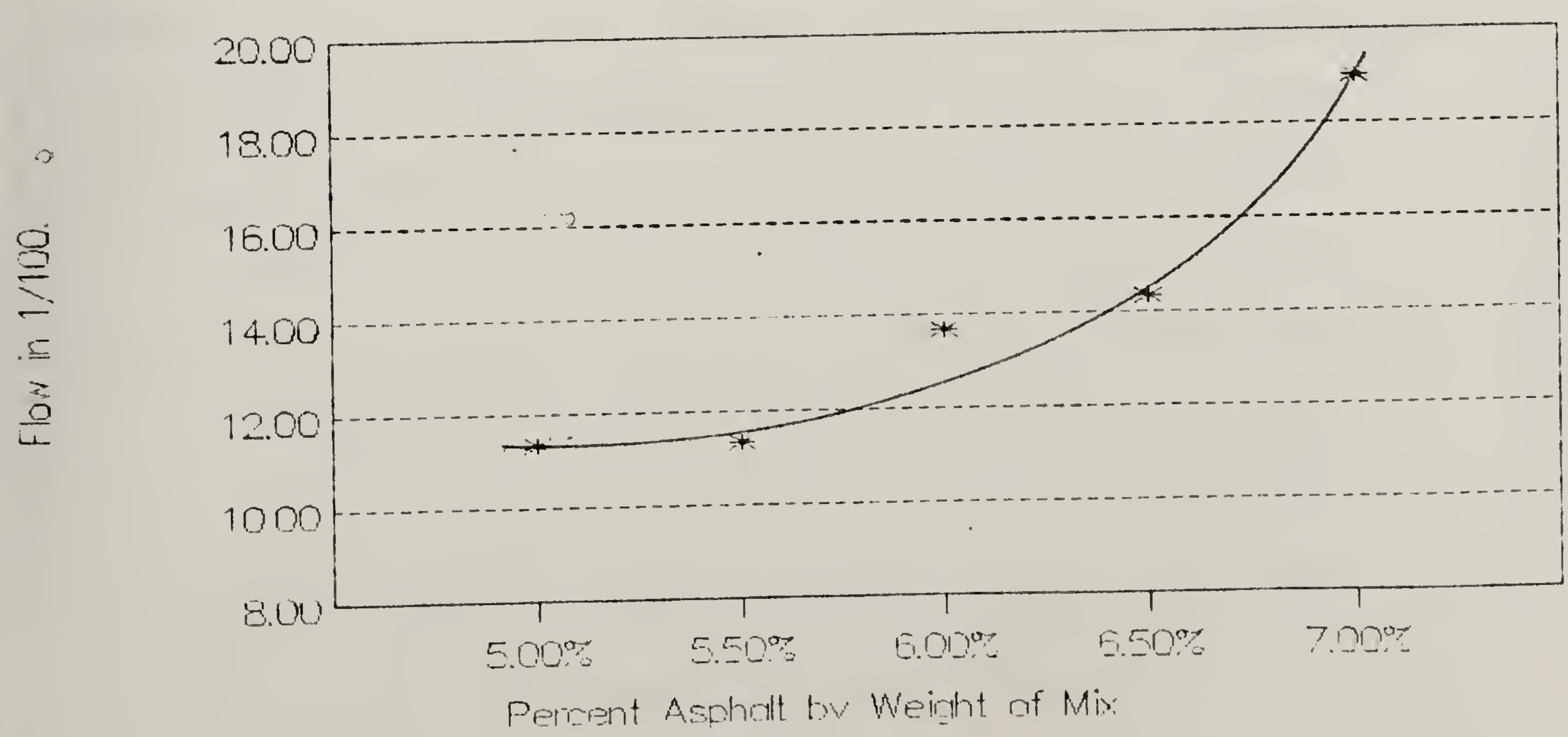
Unmodified Conoco–Stability

Controlled Aggregates



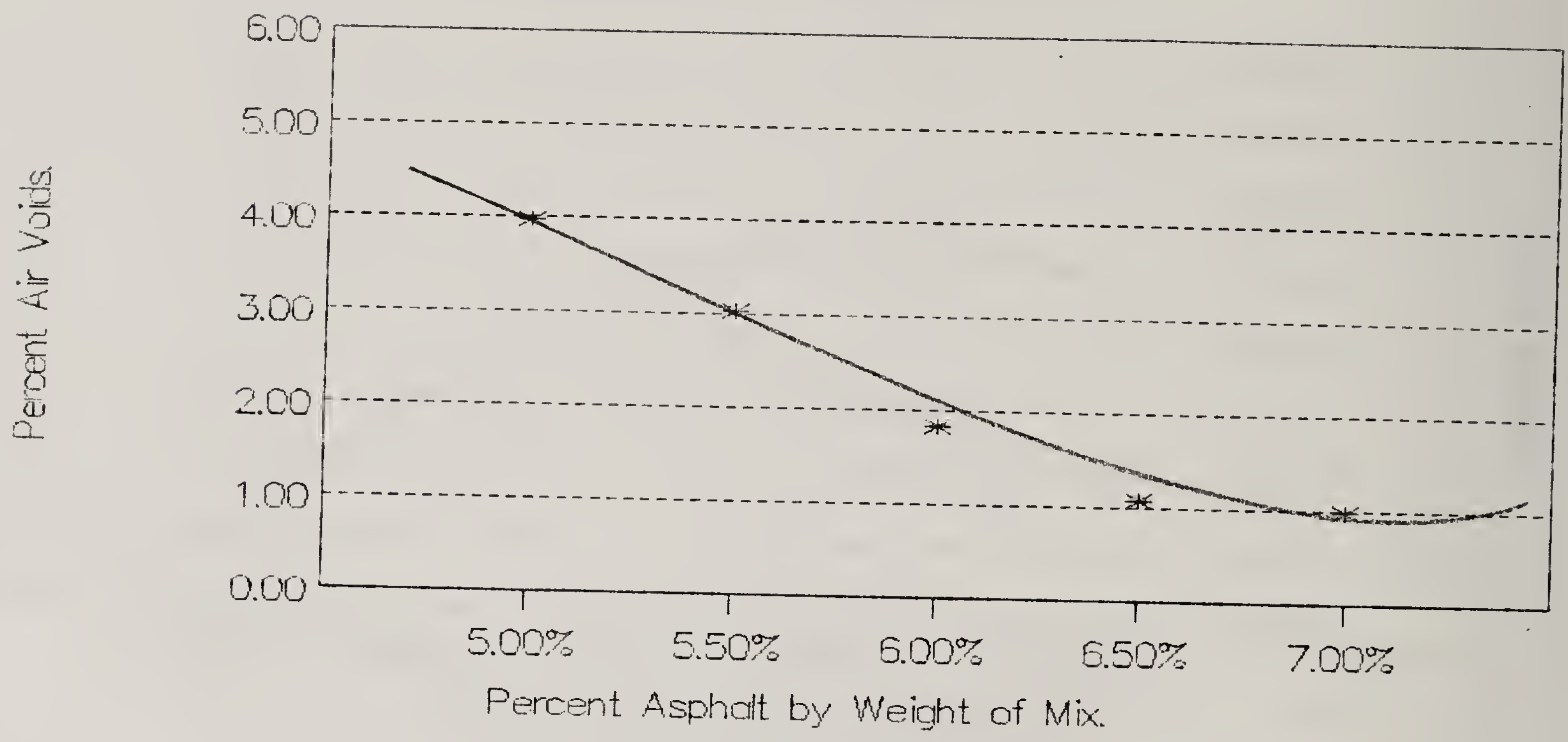
Unmodified Conoco–Flow

Controlled Aggregates



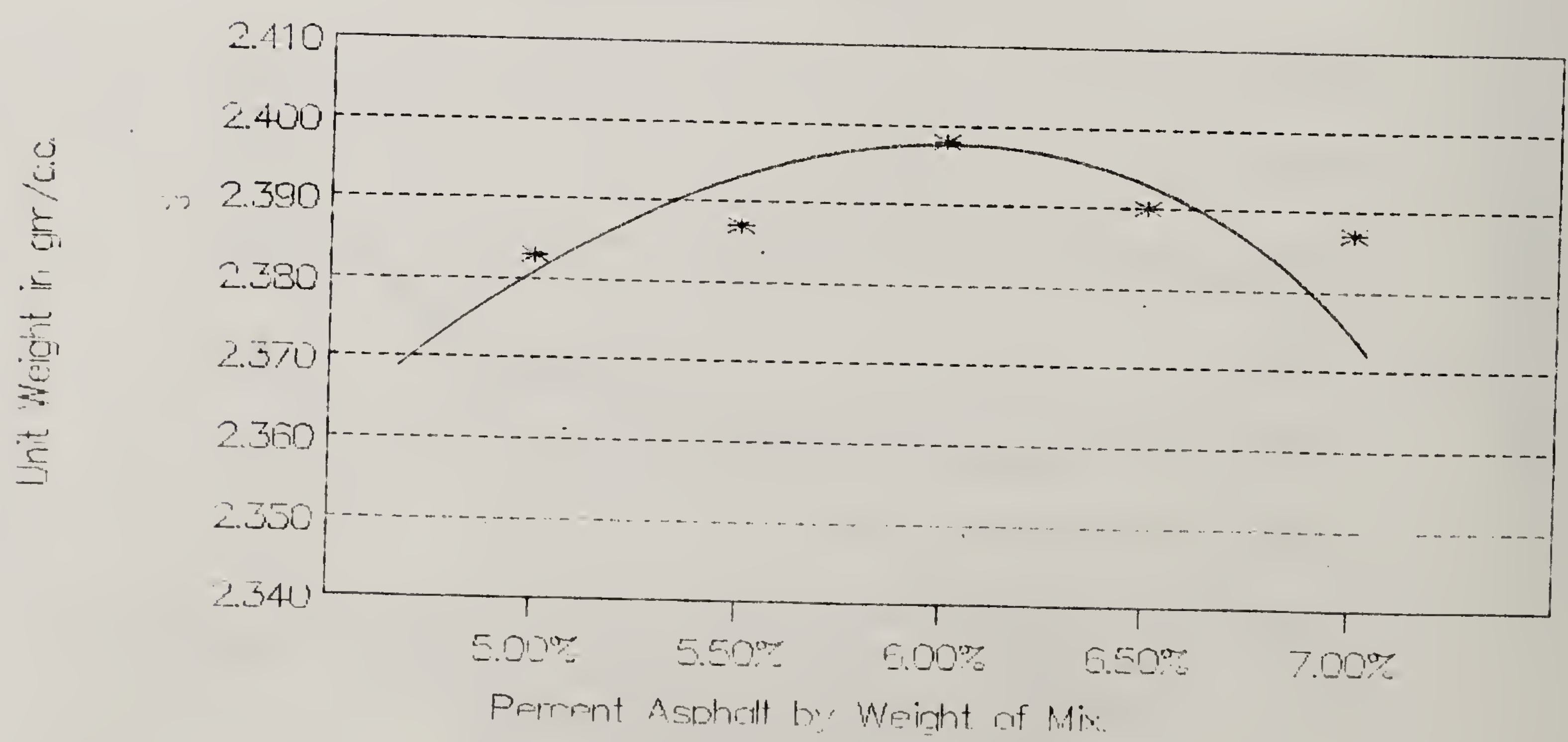
Unmodified Conoco-Percent Air Voids

Controlled Aggregates



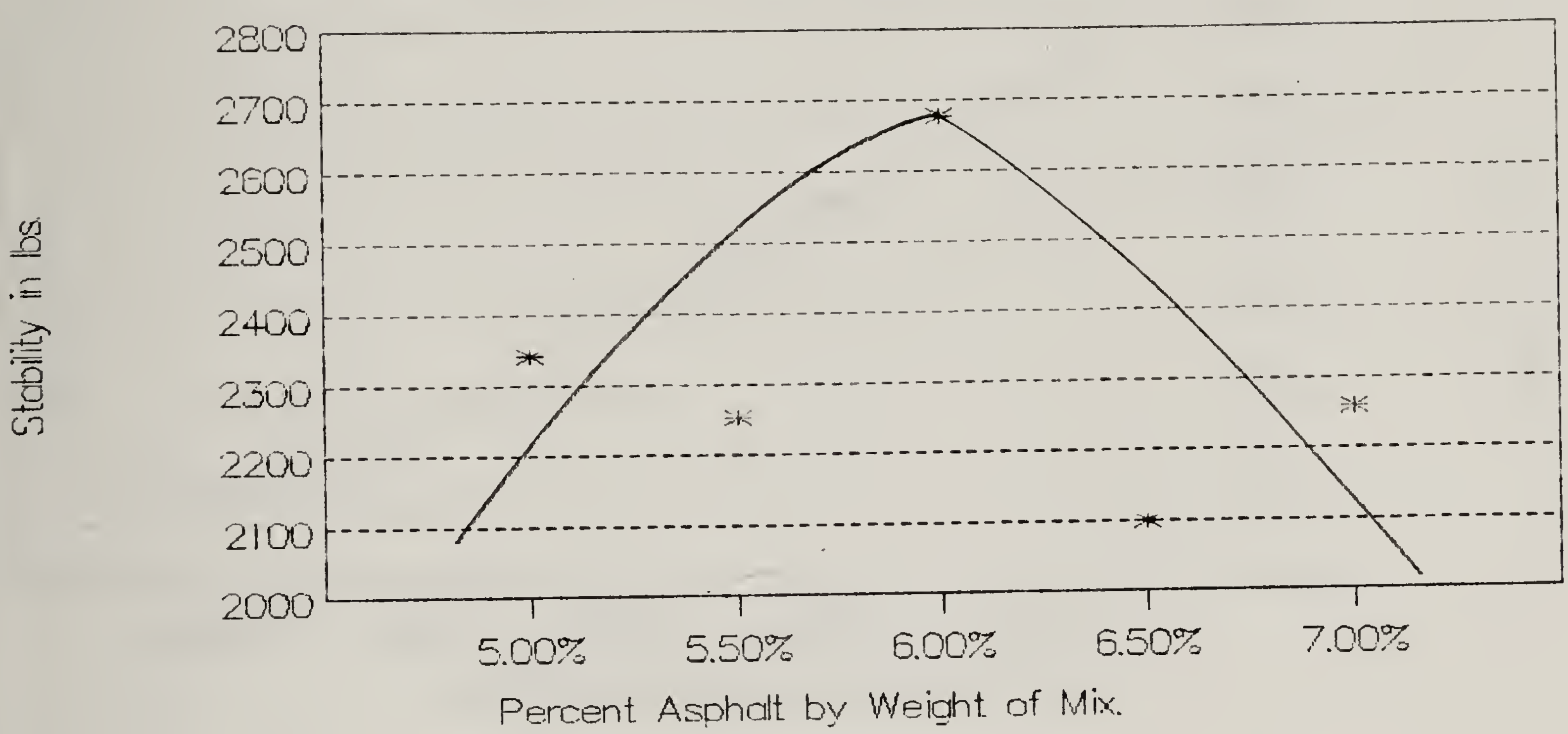
Unmodified Conoco-Unit Weight

Controlled Aggregates



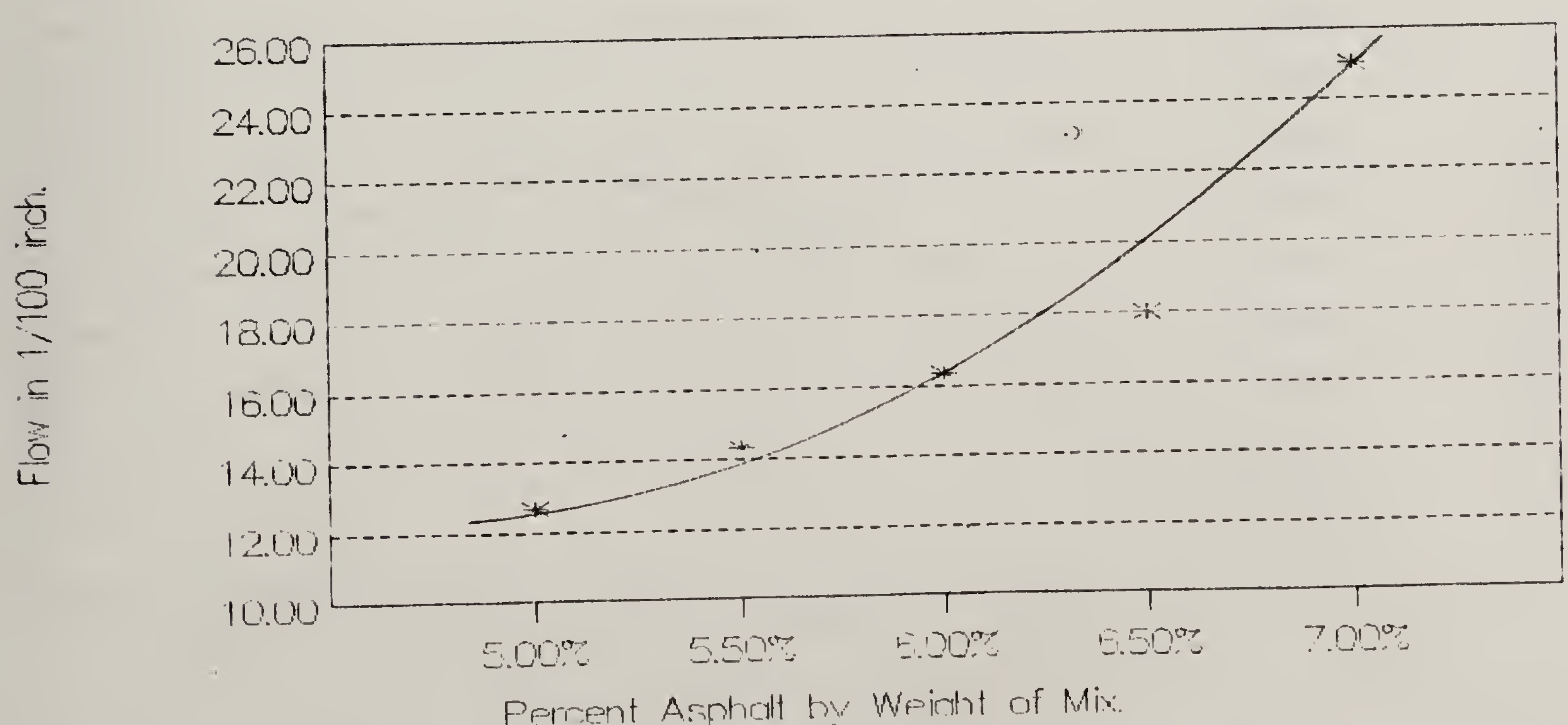
Kraton(6%) Mod. Conoco–Stability

Controlled Aggregates



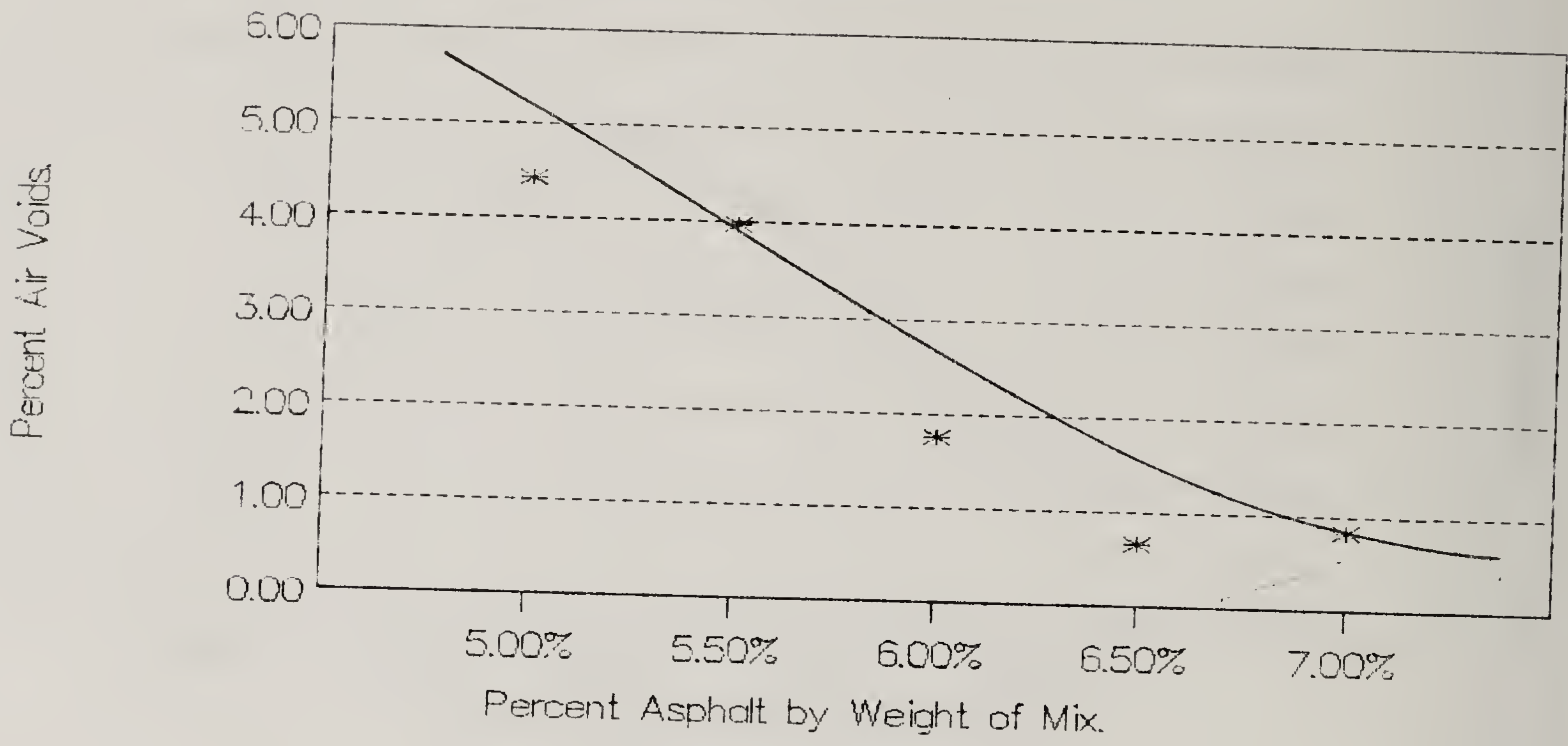
Kraton(6%) Mod. Conoco–Flow

Controlled Aggregates



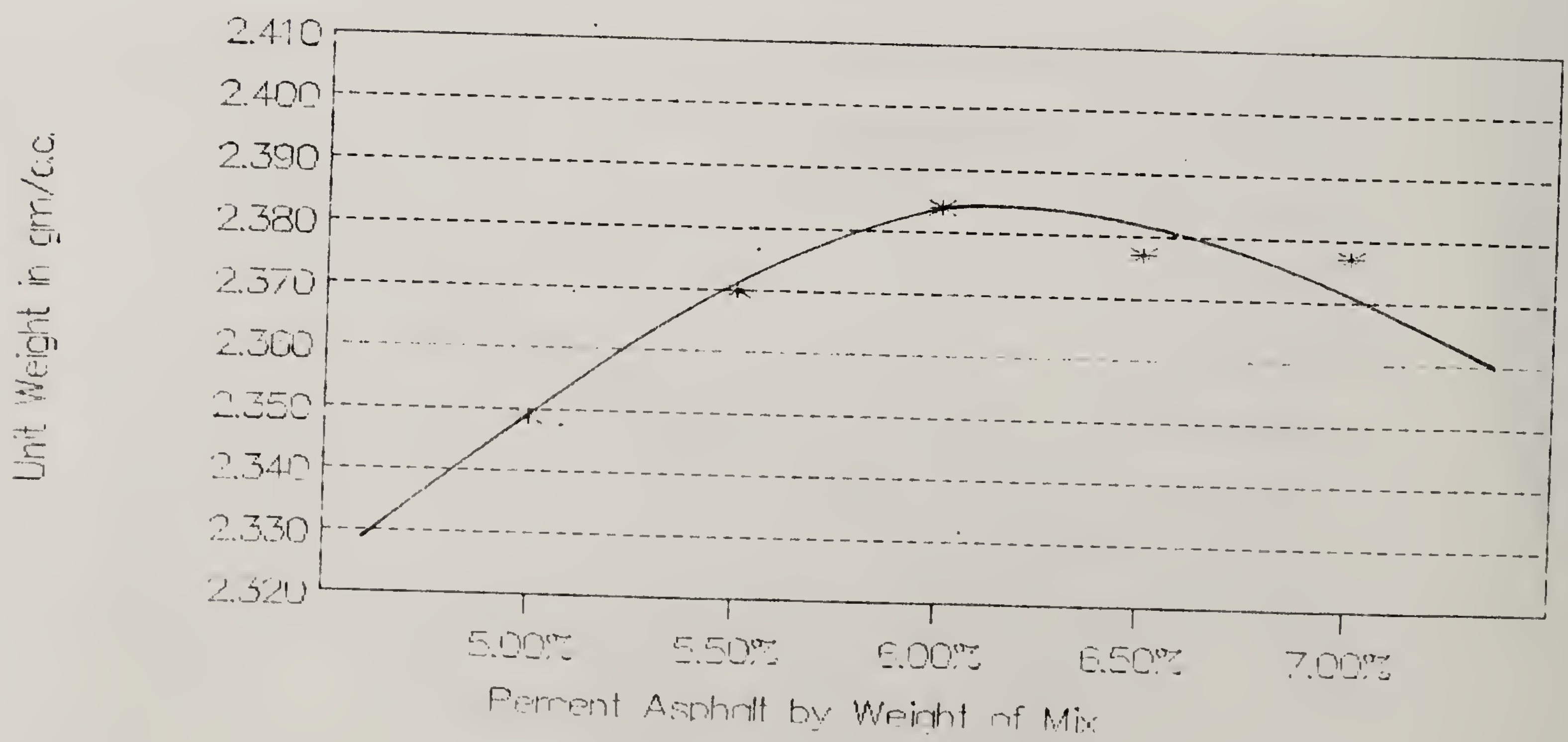
Kraton(6%) Mod. Conoco–Percent Air Void

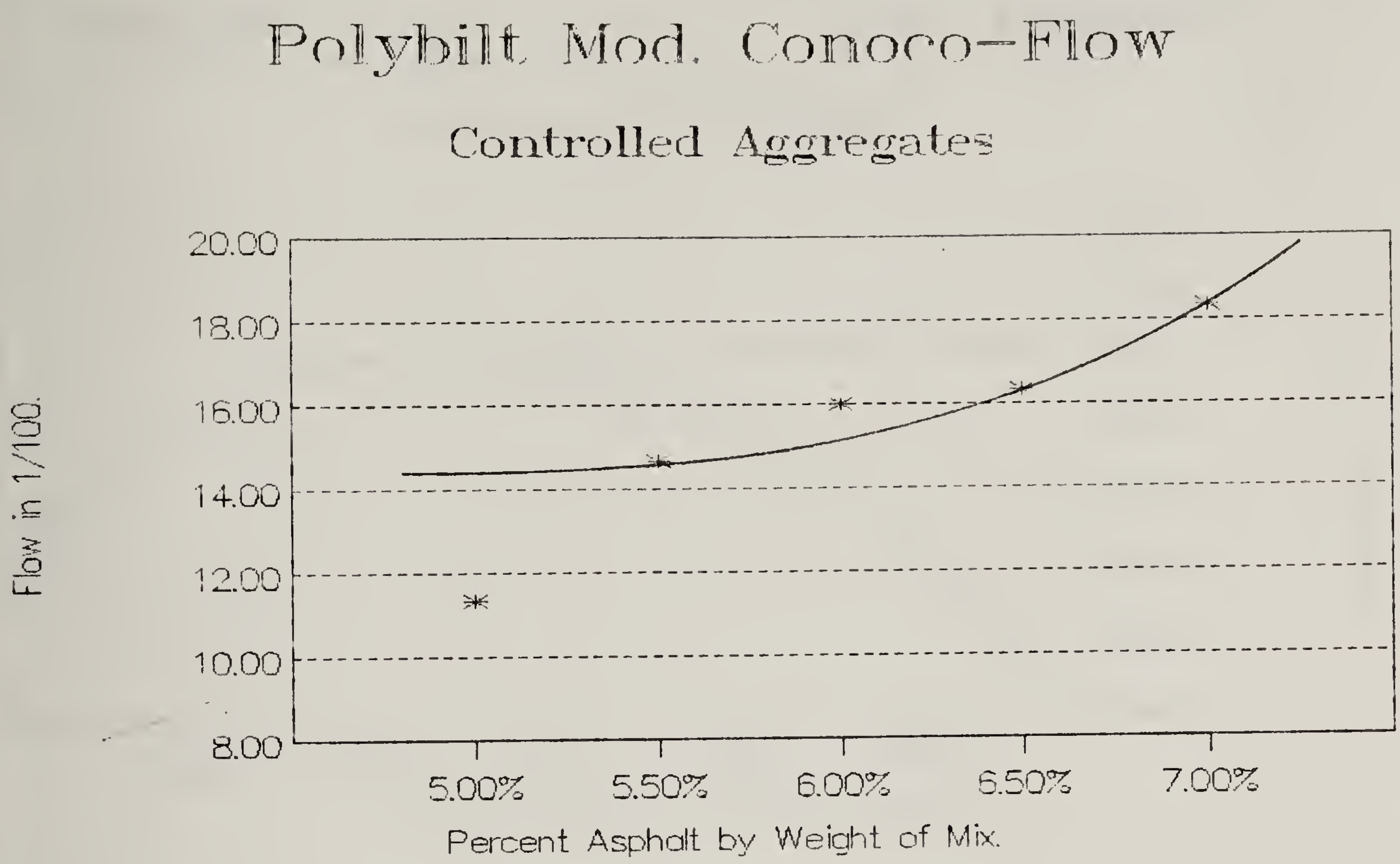
Controlled Aggregates

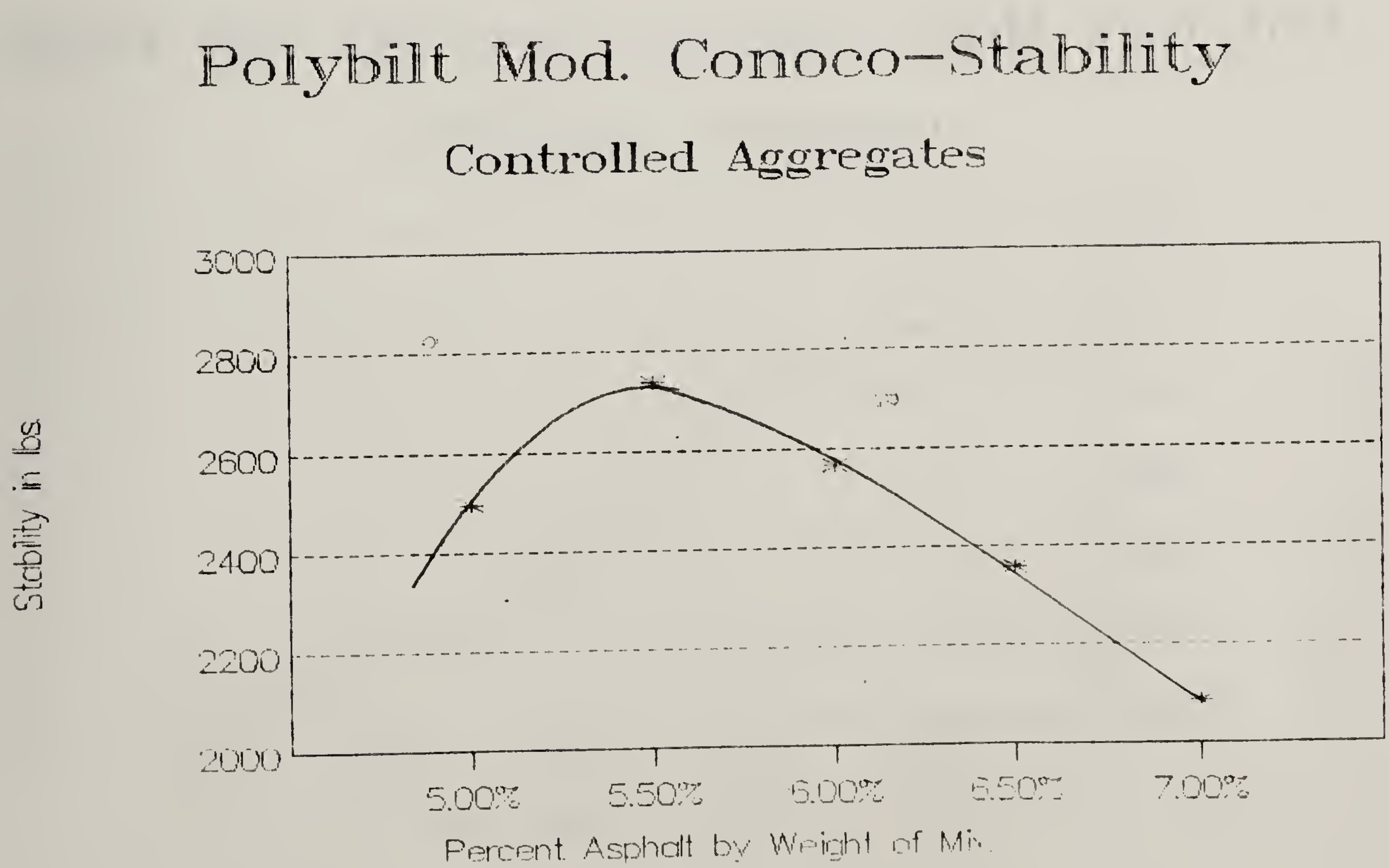


Kraton(6%) Mod. Conoco–Unit Weight

Controlled Aggregates

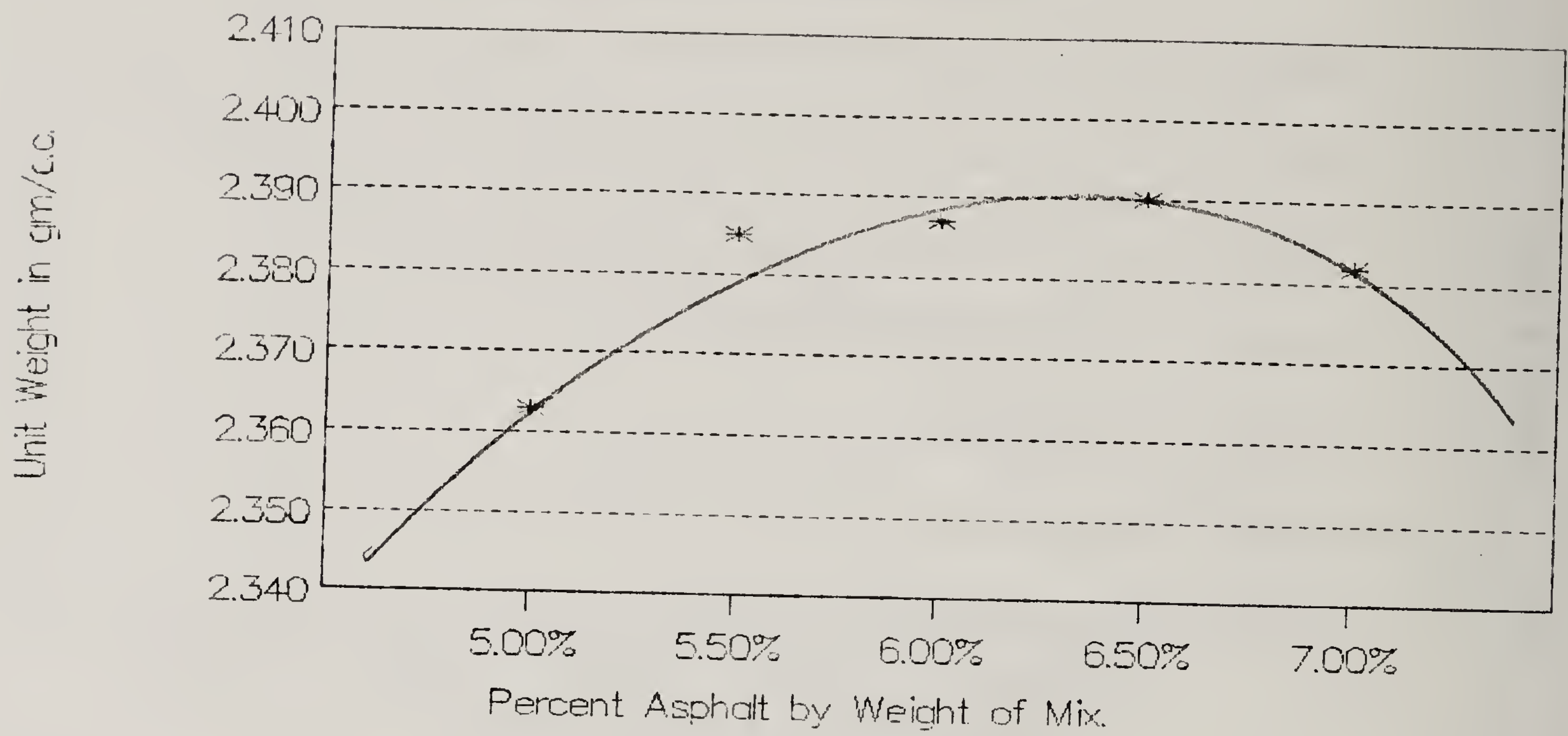



Polybilt Mod. Conoco-Flow
Controlled Aggregates
Flow in 1/100.
20.00
18.00
16.00
14.00
12.00
10.00
8.00
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.


Polybilt Mod. Conoco-Stability
Controlled Aggregates
Stability in lbs.
3000
2800
2600
2400
2200
2000
5.00%
5.50%
6.00%
6.50%
7.00%
Percent Asphalt by Weight of Mix.

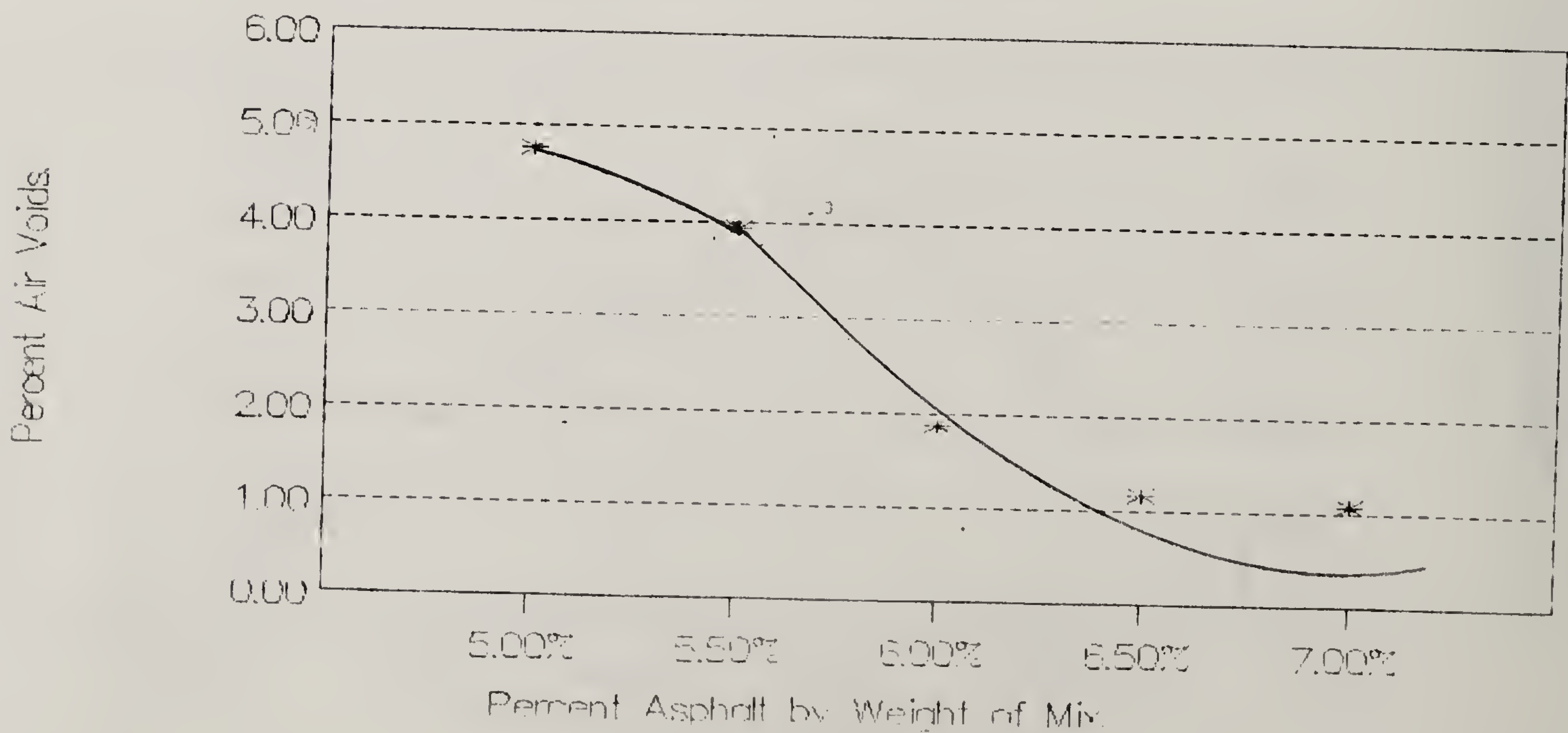
Polybilt Mod. Conoco–Unit Weight

Controlled Aggregates



Polybilt Mod. Conoco–Percent Air Voids

Controlled Aggregates



Appendix C. Test Data Sheet

Appendix C. Marshall Specimen Preparation Record for Split Aggregate, 75 Blows Compaction.

Asphalt Percent	Sample Number	Asphalt Weight	Sample Weight	Aggregate Temp.	Asphalt Temp.	Mix Temp. Before Pounding
Cenex 4%	I	48.5	1164.5	325	268	296
	II	46.7	1120.8	325	262	295
	III	48.3	1160.1	320	259	280
Cenex 4.5%	I	55.5	1166.8	330	275	295
	II	54.8	1163.9	338	265	298
	III	54.7	1160.5	328	260	285
Cenex 5.0%	I	60.2	1143.7	330	260	290
	II	58.8	1116.5	330	265	290
	III	60.0	1139.2	330	260	290
Cenex 5.5%	I	66.6	1143.8	340	278	300
	II	65.5	1125.6	330	260	296
	III	66.4	1140.2	325	252	283
Cenex 6.0%	I	75.2	1177.6	325	255	283
	II	73.1	1144.9	329	269	290
	III	73.5	1151.9	329	255	290
Conoco 4.5%	I	53.1	1127.9	332	255	287
	II	52.8	1121.4	333	255	288
	III	53.9	1144.8	325	245	288
Conoco 5.0%	I	59.5	1130.2	330	255	288
	II	62.2	1180.9	326	262	286
	III	60.3	1146.6	328	275	282
Conoco 5.5%	I	68.8	1181.9	337	275	285
	II	65.0	1116.8	340	260	295
	III	64.2	1130.8	330	255	280
Conoco 6.0%	I	69.2	1084.5	315	270	285
	II	75.4	1178.9	310	265	280
	III	75.9	1188.8	310	270	280
Conoco 6.5%	I	82.3	1184.5	310	265	280
	II	82.6	1187.5	310	265	280
	III	82.0	1179.5	305	265	278

Appendix C. Marshall Specimen Preparation Record for Controlled Aggregate, 50 Blows Compaction.

Asphalt Percent	Sample Number	Asphalt Weight	Sample Weight	Aggregate Temp.	Asphalt Temp. Pounding	Mix Temp. Before
Cenex 5.0%	I	60.2	1143.4	310	290	285
	II	60.5	1149.1	340	270	300
	III	60.3	1145.3	335	270	298
Cenex 5.5%	I	66.6	1144.8	332	270	295
	II	66.5	1142.3	335	275	290
	III	66.7	1145.3	315	255	294
Cenex 6.0%	I	73.0	1144.3	315	260	295
	II	73.1	1144.8	333	252	291
	III	73.2	1146.6	325	240	287
Cenex 6.5%	I	79.7	1146.7	326	279	285
	II	79.7	1146.2	322	265	285
	III	79.4	1142.3	325	260	295
Cenex 7.0%	I	86.3	1146.4	334	253	296
	II	86.2	1145.2	331	265	294
	III	86.2	1145.8	310	260	290
Kr-Ce(6) 5.0%	I	60.2	1143.9	335	275	300
	II	60.3	1145.8	310	260	292
	III	60.4	1147.8	330	275	295
Kr-Ce(6) 5.5%	I	66.6	1144.5	336	294	289
	II	66.6	1145.1	338	265	297
	III	66.7	1146.5	310	270	288
Kr-Ce(6) 6.0%	I	73.3	1148.7	330	270	290
	II	73.0	1143.6	312	262	295
	III	73.0	1143.2	340	275	303
Kr-Ce(6) 6.5%	I	79.7	1146.6	325	267	286
	II	79.6	1147.1	315	270	295
	III	79.7	1147.1	315	265	295
Kr-Ce(6) 7.0%	I	86.0	1142.5	340	275	295
	II	86.3	1146.2	325	331	285
	III	86.3	1146.5	331	280	285

Appendix C. Marshall Specimen Preparation Record for Controlled Aggregate, 50 Blows Compaction.

Asphalt Percent	Sample Number	Asphalt Weight	Sample Weight	Aggregate Temp.	Asphalt Temp.	Mix Temp. Before Pounding
Poly-Ce 5.0%	I	60.2	1144.3	310	250	287
	II	60.2	1143.8	335	270	295
	III	60.4	1148.5	335	260	295
Poly-Ce 5.5%	I	66.6	1145.0	335	275	295
	II	66.5	1148.8	335	265	290
	III	66.7	1146.8	326	246	289
Poly-Ce 6.0%	I	73.1	1145.0	330	285	295
	II	73.0	1143.3	315	260	295
	III	73.2	1146.6	325	260	288
Poly-Ce 6.5%	I	79.6	1145.0	315	280	295
	II	79.5	1144.1	322	256	286
	III	79.6	1144.5	323	243	286
Poly-Ce 7%	I	86.1	1143.9	336	265	305
	II	86.8	1144.6	300	260	293
	III	86.4	1147.3	328	270	295
Conoco 5.0%	I	60.1	1141.8	325	255	293
	II	60.3	1145.3	325	270	298
	III	60.2	1143.7	316	249	289
Conoco 5.5%	I	66.6	1144.0	319	252	284
	II	66.5	1143.1	325	256	284
	III	66.7	1145.6	320	270	285
Conoco 6.0%	I	73.0	1144.2	325	264	286
	II	73.0	1143.8	314	260	289
	III	73.1	1144.6	321	276	295
Conoco 6.5%	I	79.5	1144.1	322	270	292
	II	79.5	1143.3	311	261	283
	III	79.5	1143.3	316	281	289
Conoco 7.0%	I	86.2	1144.8	329	276	298
	II	86.3	1146.0	320	278	292
	III	86.0	1142.6	322	266	292

Appendix C. Marshall Specimen Preparation Record for Controlled Aggregate, 50 Blows Compaction.

Asphalt Percent	Sample Number	Asphalt Weight	Sample Weight	Aggregate Temp.	Asphalt Temp.	Mix Temp. Before Pounding
Kr-Co(6) 5.0%	I	60.2	1144.4	315	272	282
	II	60.1	1142.3	318	275	290
	III	60.2	1143.3	324	263	281
Kr-Co(6) 5.5%	I	66.5	1143.1	319	270	276
	II	66.5	1142.6	332	271	295
	III	66.6	1143.9	320	275	288
Kr-Co(6) 6.0%	I	73.1	1144.6	338	276	292
	II	72.8	1140.8	330	266	290
	III	73.1	1144.6	320	283	290
Kr-Co(6) 6.5%	I	79.7	1145.9	327	272	289
	II	79.5	1143.7	323	271	288
	III	79.5	1143.8	318	279	282
Kr-Co(6) 7.0%	I	86.1	1144.2	328	289	291
	II	86.1	1143.8	320	278	286
	III	96.0	1142.8	307	275	280
Poly-Co 5.0%	I	60.3	1145.0	333	256	295
	II	60.2	1144.0	322	250	282
	III	60.1	1142.3	312	256	283
Poly-Co 5.5%	I	66.7	1145.6	325	259	290
	II	66.5	1142.7	319	256	288
	III	66.6	1143.8	310	275	277
Poly-Co 6.0%	I	72.9	1142.8	329	255	291
	II	73.1	1145.1	335	280	295
	III	73.1	1145.7	322	265	291
Poly-Co 6.5%	I	79.4	1142.6	316	266	286
	II	79.5	1143.9	315	270	277
	III	79.6	1145.0	315	260	283
Poly-Co 7.0%	I	86.0	1143.2	315	275	285
	II	86.1	1143.3	325	269	286
	III	86.3	1146.5	315	265	284

Appendix D. Experimental Design Results

Experimental Design

ANOVA Analysis

for

Modified and Unmodified Cenex

```
Infile den;
  Input ASPHALT PERCENT DENSITY;
Proc GLM;
  Classes ASPHALT PERCENT;
Model DENSITY=ASPHALT PERCENT ASPHALT*PERCENT;
  Means ASPHALT PERCENT/SNK;
Proc Plot;
  Plot DENSITY*PERCENT=ASPHALT;
       Title 'DENSITY vs. PERCENT/ASPHALT';
  Plot DENSITY*ASPHALT=PERCENT;
```

SAS — 20:26 WEDNESDAY, MARCH 7, 1990 2

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	14	0.00797391	0.00056957	2.20	0.0340	0.506991	0.6781
ERROR	30	0.00775400	0.00025847		ROOT MSE		DENSITY MEAN
CORRECTED TOTAL	44	0.01572791			0.01607690		2.37084444

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
ASPHALT	2	0.00284538	5.50	0.0092 *	2	0.00284538	5.50	0.0092
PERCENT	4	0.00400658	3.88	0.0118 *	4	0.00400658	3.88	0.0118
ASPHALT*PERCENT	8	0.00112196	0.54	0.8149	8	0.00112196	0.54	0.8149

$F_{.05}$ (Critical F :

$F_{.05}(2,30) = 3.32$

$F_{.05}(4,30) = 2.69$

$F_{.05}(8,30) = 2.2$[illegible]

SAS — 20:27 WEDNESDAY, MARCH 7, 1990 3

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=30 MSE=2.6E-04

NUMBER OF MEANS	2	3
CRITICAL RANGE	0.0119892	0.0144722

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	ASPHALT
A	2.376600	15	1
A			

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	14	0.00797391	0.00056957	2.20	0.0340	0.506991	0.6781
ERROR	30	0.00775400	0.00025847		ROOT MSE		DENSITY MEAN
CORRECTED TOTAL	44	0.01572791			0.01607690		2.37084444

SOURCE	DF	TYPE I SS	F VALUE	PR > F		DF	TYPE III SS	F VALUE	PR > F
ASPHALT	2	0.00284538	5.50	0.0092	*	2	0.00284538	5.50	0.0092
PERCENT	4	0.00400658	3.88	0.0118	*	4	0.00400658	3.88	0.0118
ASPHALT*PERCENT	8	0.00112196	0.54	0.8149		8	0.00112196	0.54	0.8149

$F_{.05}$ (Critical F

$F_{.05}(2,30) = 3.32$
$F_{.05}(4,30) = 2.69$
$F_{.05}(8,30) = 2.2$

SAS 20:27 WEDNESDAY, MARCH 7, 1990 4

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=30 MSE=2.6E-04

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	0.015478	0.0186836	0.0206073	0.0219829

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	PERCENT
	A	2.383333	9	3
	A			
B	A	2.374222	9	4
B	A			
B	A	2.372000	9	2
B	A			
B	A	2.370444	9	5
B				
B		2.354222	9	1

```
Data;
  Infile asp;
  Input ASPHALT PERCENT STABLE;
Proc GLM;
  Classes ASPHALT PERCENT;
Model STABLE=ASPHALT PERCENT ASPHALT*PERCENT;
  Means ASPHALT PERCENT/SNK;
Proc Plot;
  Plot STABLE*PERCENT=ASPHALT;
       Title 'STABILITY vs. PERCENT/ASPHALT';
  Plot STABLE*ASPHALT=PERCENT;
```


GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABLE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	14	1925258.31111111	137518.45079365	1.59	0.1384	0.426628	13.1211
ERROR	30	2587472.00000000	86249.06666667		ROOT MSE		STABLE MEAN
CORRECTED TOTAL	44	4512730.31111111			293.68191410		2238.24444444

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
ASPHALT	2	161892.84444444	0.94	0.4024	2	161892.84444444	0.94	0.4024
PERCENT	4	1463306.53333333	4.24	0.0077 *	4	1463306.53333333	4.24	0.0077
ASPHALT*PERCENT	8	300058.93333333	0.43	0.8905	8	300058.93333333	0.43	0.8905

$F_{.05}$ Critical F

$F_{.05}(2,\infty) = 3.32$
$F_{.05}(4,\infty) = 2.69$
$F_{.05}(8,\infty) = 2.21$

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABLE

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=30 MSE=86249.1

NUMBER OF MEANS	2	3
CRITICAL RANGE	219.01	264.369

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	ASPHALT

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABLE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	14	1925258.31111111	137518.45079365	1.59	0.1384	0.426628	13.1211
ERROR	30	2587472.00000000	86249.06666667		ROOT MSE		STABLE MEAN
CORRECTED TOTAL	44	4512730.31111111			293.68191410		2238.24444444

SOURCE	DF	TYPE I SS	F VALUE	PR > F		DF	TYPE III SS	F VALUE	PR > F
ASPHALT	2	161892.84444444	0.94	0.4024		2	161892.84444444	0.94	0.4024
PERCENT	4	1463306.53333333	4.24	0.0077	*	4	1463306.53333333	4.24	0.0077
ASPHALT*PERCENT	8	300058.93333333	0.43	0.8905		8	300058.93333333	0.43	0.8905

$F_{.05}$ (Critical F...

$F_{.05}(2,30) = 3.32$
$F_{.05}(4,30) = 2.69$
$F_{.05}(8,30) = 2.21$

SAS 20:13 WEDNESDAY, MARCH 7, 1990 4

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABLE
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=30 MSE=86249.1

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	282.741	341.299	376.441	401.569

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	PERCENT
A	2399.3	9	3
A			
A	2379.0	9	2
A			
A	2264.1	9	1
A			
A	2251.1	9	4
B	1897.7	9	5

Experimental Design

One Way ANOVA Analysis

for

Modified and Unmodified Cenex

by

Asphalt Content

SAS 15:26 FRIDAY, MARCH 16, 1990 1

TYPE=Conex

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN BY GROUP = 15

SAS 15:26 FRIDAY, MARCH 16, 1990 2

TYPE=Conex

GENERAL LINEAR MODELS PROCEDURE

NDENT VARIABLE: DENSITY

CE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
L	4	0.00218693	0.00054673	1.40
R	10	0.00390067	0.00039007	PR > F
ECTED TOTAL	14	0.00608760		0.3020

UARE	C.V.	ROOT MSE	DENSITY MEAN
59244	0.8310	0.01975011	2.37660000

RCE	DF	TYPE I SS	F VALUE	PR > F
TENT	4	0.00218693	1.40	0.3020

RCE	DF	TYPE III SS	F VALUE	PR > F
TENT	4	0.00218693	1.40	0.3020

SAS 15:26 FRIDAY, MARCH 16, 1990 4

TYPE=Conex

GENERAL LINEAR MODELS PROCEDURE

UDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
TE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=10 MSE=3.9E-04

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	0.0359307	0.0442059	0.0493374	0.0530733

EANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	CONTENT
A	2.39467	3	6
A	2.38133	3	7
A	2.37933	3	5.5
A	2.36867	3	6.5
A	2.35900	3	5

SAS 15:26 FRIDAY, MARCH 16, 1990

TYPE=Cenex

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN BY GROUP = 15

SAS 15:26 FRIDAY, MARCH 16, 1990 3

TYPE=Cenex

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	4	462842.26666667	115710.56666667	1.44
ERROR	10	803864.46666667	80386.44666667	PR > F
CORRECTED TOTAL	14	1266706.73333333		0.2910

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.365390	12.9153	283.52507238	2195.26666667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
CONTENT	4	462842.26666667	1.44	0.2910

SOURCE	DF	TYPE III SS	F VALUE	PR > F
CONTENT	4	462842.26666667	1.44	0.2910

SAS 15:26 FRIDAY, MARCH 16, 1

TYPE=Cenex

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=10 MSE=80386.5

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	515.807	634.603	708.269	761.9

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	CONTENT
A	2426.7	3	6
A			
A	2330.3	3	5.5
A			
A	2225.0	3	5
A			
A	2036.7	3	6.5
A			
A	1957.7	3	7

SAS 15:26 FRIDAY, MARCH 16, 1990 6

TYPE=Kr(6)-Ce

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN BY GROUP = 15

SAS 15:26 FRIDAY, MARCH 16, 1990

TYPE=Kr(6)-Ce

GENERAL LINEAR MODELS PROCEDURE

DENT VARIABLE: DENSITY

E	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
	4	0.00102893	0.00025723	0.E
	10	0.00300467	0.00030047	PR >
ECTED TOTAL	14	0.00403360		0.521

JARE	C.V.	ROOT MSE	DENSITY MEAN
5091	0.7346	0.01733397	2.35960000

CE	DF	TYPE I SS	F VALUE	PR > F
ENT	4	0.00102893	0.86	0.5219

CE	DF	TYPE III SS	F VALUE	PR > F
ENT	4	0.00102893	0.86	0.5219

SAS 15:26 FRIDAY, MARCH 16, 1990

TYPE=Kr(6)-Ce

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=10 MSE=3.0E-04

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	0.0315351	0.0387979	0.0433017	0.0465806

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	CONTENT
A	2.37067	3	6.5
A	2.36367	3	6
A	2.35933	3	5.5
A	2.35900	3	7
A	2.34533	3	5

SAS 15:24 FRIDAY, MARCH 16, 1990 6

TYPE=Kr(6)-Ce

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN BY GROUP = 15

SAS 15:24 FRIDAY, MARCH 16, 1990 8

TYPE=Kr(6)-Ce

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	4	679159.73333333	169789.93333333	2.23
ERROR	10	761312.00000000	76131.20000000	PR > F
CORRECTED TOTAL	14	1440471.73333333		0.1385

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.471484	12.7179	275.91882864	2169.53333333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
CONTENT	4	679159.73333333	2.23	0.1385

SOURCE	DF	TYPE III SS	F VALUE	PR > F
CONTENT	4	679159.73333333	2.23	0.1385

SAS 15:24 FRIDAY, MARCH 16, 1990 10

TYPE=Kr(6)-Ce

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=10 MSE=76131.2

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	501.969	617.570	689.268	741.46

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	CONTENT
A	2316.7	3	5.5
A			
A	2306.0	3	5
A			
A	2258.3	3	6
A			
A	2216.7	3	6.5
A			
A	1750.0	3	7

```
                         SAS            15:26 FRIDAY, MARCH 16, 1990 11
                    TYPE=Poly-Ce
        GENERAL LINEAR MODELS PROCEDURE
            CLASS LEVEL INFORMATION
      CLASS       LEVELS      VALUES
      CONTENT          5      5 6 7 5.5 6.5

   NUMBER OF OBSERVATIONS IN BY GROUP = 15

                           SAS          15:26 FRIDAY, MARCH 16, 1990 13
                       TYPE=Poly-Ce
            GENERAL LINEAR MODELS PROCEDURE
NT VARIABLE: STABILIT
                DF        SUM OF SQUARES           MEAN SQUARE       F VALUE
                 4     462494.26666667       115623.56666667          1.27
                10     911460.66666667        91146.06666667        PR > F
ED TOTAL        14    1373954.93333333                                0.3447

F           C.V.               ROOT MSE          STABILIT MEAN
5        12.9959           301.90406865          2323.06666667

                DF            TYPE I SS     F VALUE     PR > F
                 4      462494.26666667        1.27     0.3447

                DF          TYPE III SS     F VALUE     PR > F
                 4      462494.26666667        1.27     0.3447
                            SAS         15:26 FRIDAY, MARCH 16, 1990 15
                       TYPE=Poly-Ce
             GENERAL LINEAR MODELS PROCEDURE
   STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
   NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
         UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
         NULL HYPOTHESES
                ALPHA=0.05   DF=10   MSE=91146.1

    NUMBER OF MEANS          2          3          4          5
    CRITICAL RANGE     549.243     675.74    754.181    811.289

   MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.
      SNK       GROUPING               MEAN        N   CONTENT
                       A             2485.0        3   6
                       A
                       A             2438.0        3   6.5
                       A
                       A             2425.0        3   5.5
                       A
                       A             2261.3        3   5
                       A
                       A             2006.0        3   7
```

SAS 15:26 FRIDAY, MARCH 16, 1990 11

TYPE=Poly-Ce

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN BY GROUP = 15

SAS 15:26 FRIDAY, MARCH 16, 1990 12

TYPE=Poly-Ce

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	4	0.00191267	0.00047817	5.63
ERROR	10	0.00084867	0.00008487	PR > F
CORRECTED TOTAL	14	0.00276133		0.0122

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.692661	0.3877	0.00921231	2.37633333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
CONTENT	4	0.00191267	5.63	0.0122

SOURCE	DF	TYPE III SS	F VALUE	PR > F
CONTENT	4	0.00191267	5.63	0.0122

SAS 15:26 FRIDAY, MARCH 16, 1990 14

TYPE=Poly-Ce

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=10 MSE=8.5E-05

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	0.0167596	0.0206195	0.0230131	0.0247557

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	CONTENT
	A	2.391667	3	6
	A			
	A	2.383333	3	6.5
	A			
B	A	2.377333	3	5.5
B	A			
B	A	2.371000	3	7
B				
B		2.358333	3	5

SAS 15:36 FRIDAY, MARCH 16, 1990 1

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
TYPE	3	Cenex Kr(6)-Ce Poly-Ce
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN DATA SET = 45

SAS 15:36 FRIDAY, MARCH 16, 1990 2

GENERAL LINEAR MODELS PROCEDURE

DENT VARIABLE: DENSITY

E	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
	14	0.00797371	0.00056957	2.20
	30	0.00775400	0.00025847	PR > F
CTED TOTAL	44	0.01572771		0.0340

ARE	C.V.	ROOT MSE	DENSITY MEAN
991	0.6781	0.01607690	2.37084444

E	DF	TYPE I SS	F VALUE	PR > F
	2	0.00284538	5.50	0.0092
NT	4	0.00400658	3.88	0.0118
CONTENT	8	0.00112196	0.54	0.8149

E	DF	TYPE III SS	F VALUE	PR > F
	2	0.00284538	5.50	0.0092
NT	4	0.00400658	3.88	0.0118
CONTENT	8	0.00112196	0.54	0.8149

SAS 15:36 FRIDAY, MARCH 16, 1990 4

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=30 MSE=2.6E-04

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	0.015478	0.0186836	0.0206073	0.0219829

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	CONTENT
	A	2.383333	9	6
	A	2.374222	9	6.5
B	A	2.372000	9	5.5
B	A	2.370444	9	7
B		2.354222	9	5

SAS 15:36 FRIDAY, MARCH 16, 1990 1

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
TYPE	3	Cenex Kr(6)-Ce Poly-Ce
CONTENT	5	5 6 7 5.5 6.5

NUMBER OF OBSERVATIONS IN DATA SET = 45

SAS 15:36 FRIDAY, MARCH 16, 1990 3

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	14	1807333.91111111	129095.27936508	1.56
ERROR	30	2476637.33333333	82554.57777778	PR > F
CORRECTED TOTAL	44	4283971.24444444		0.1483

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
.421883	12.8886	287.32312434	2229.28888889

SOURCE	DF	TYPE I SS	F VALUE	PR > F
TYPE	2	202837.64444444	1.23	0.3070
CONTENT	4	1340001.91111111	4.06	0.0095
TYPE*CONTENT	8	264494.35555556	0.40	0.9114

SOURCE	DF	TYPE III SS	F VALUE	PR > F
TYPE	2	202837.64444444	1.23	0.3070
CONTENT	4	1340001.91111111	4.06	0.0095
TYPE*CONTENT	8	264494.35555556	0.40	0.9114

SAS 15:36 FRIDAY, MARCH 16, 1990 5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=30 MSE=82554.6

NUMBER OF MEANS	2	3	4	5
CRITICAL RANGE	276.619	333.909	368.29	392.875

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	CONTENT
A	2390.0	9	6
A			
A	2357.3	9	5.5
A			
A	2264.1	9	5
A			
A	2230.4	9	6.5
B	1904.6	9	7

Experimental Design

One Way ANOVA Analysis

for

Split (S) and Controlled (C) Aggregate

by

Aspahlt Content

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 11:55 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.00576600	0.00576600	44.
ERROR	4	0.00052000	0.00013000	PR >
CORRECTED TOTAL	5	0.00628600		0.00

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.917276	0.4898	0.01140175	2.32800000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00576600	44.35	0.0026

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00576600	44.35	0.0026

SAS 11:55 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=1.3E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.025862

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.359000	3	C
B	2.297000	3	S

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	582193.50000000	582193.50000000	12.98
OR	4	179438.00000000	44859.50000000	PR > F
RECTED TOTAL	5	761631.50000000		0.0227

QUARE	C.V.	ROOT MSE	STABILIT MEAN
64403	11.0688	211.80061379	1913.50000000

RCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	582193.50000000	12.98	0.0227

RCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	582193.50000000	12.98	0.0227

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=44859.5

NUMBER OF MEANS	2
CRITICAL RANGE	480.416

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2225.0	3	C
B	1602.0	3	S

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 11:55 TUESDAY, MARCH 13, 199(

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VA
MODEL	1	0.00546017	0.00546017	10
ERROR	4	0.00214467	0.00053617	PR :
CORRECTED TOTAL	5	0.00760483		0.0:

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.717986	0.9857	0.02315527	2.34916667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00546017	10.18	0.0332

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00546017	10.18	0.0332

SAS 11:55 TUESDAY, MARCH 13, 1990

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=5.4E-04

NUMBER OF MEANS	2
CRITICAL RANGE	0.0525219

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.37933	3	C
B	2.31900	3	S

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	239600.16666667	239600.16666667	2.82
OR	4	340055.33333333	85013.83333333	PR > F
RECTED TOTAL	5	579655.50000000		0.1685

QUARE	C.V.	ROOT MSE	STABILIT MEAN
.13349	13.6856	291.57131775	2130.50000000

JRCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	239600.16666667	2.82	0.1685

JRCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	239600.16666667	2.82	0.1685

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=85013.8

NUMBER OF MEANS 2
CRITICAL RANGE 661.356

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2330.3	3	C
A			
A	1930.7	3	S

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 11:56 TUESDAY, MARCH 13, 1990

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VA
MODEL	1	0.01066817	0.01066817	164.
ERROR	4	0.00025933	0.00006483	PR >
CORRECTED TOTAL	5	0.01092750		0.00

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.976268	0.3423	0.00805191	2.35250000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.01066817	164.55	0.0002

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.01066817	164.55	0.0002

SAS 11:56 TUESDAY, MARCH 13, 1990

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=6.5E-05

NUMBER OF MEANS 2
CRITICAL RANGE 0.0182637

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.394667	3	C
B	2.310333	3	S

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	526880.66666667	526880.66666667	17.76
OR	4	118650.66666667	29662.66666667	PR > F
RECTED TOTAL	5	645531.33333333		0.0135

QUARE	C.V.	ROOT MSE	STABILIT MEAN
16197	8.0846	172.22853035	2130.33333333

RCE	DF	TYPE I SS	F VALUE	PR > F
REGAT	1	526880.66666667	17.76	0.0135

RCE	DF	TYPE III SS	F VALUE	PR > F
REGAT	1	526880.66666667	17.76	0.0135

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=29662.7

NUMBER OF MEANS	2
CRITICAL RANGE	390.657

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2426.7	3	C
B	1834.0	3	S

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.00077067	0.00077067	1.
ERROR	4	0.00160067	0.00040017	PR >
CORRECTED TOTAL	5	0.00237133		0.23

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.324993	0.8486	0.02000417	2.35733333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00077067	1.93	0.2375

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00077067	1.93	0.2375

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=4.0E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0453744

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.36867	3	C
A			
A	2.34600	3	S

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	140.16666667	140.16666667	0.00
OR	4	271996.66666667	67999.16666667	PR > F
RECTED TOTAL	5	272136.83333333		0.9660

QUARE	C.V.	ROOT MSE	STABILIT MEAN
00515	12.8340	260.76649836	2031.83333333

JRCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	140.16666667	0.00	0.9660

JRCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	140.16666667	0.00	0.9660

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=67999.2

NUMBER OF MEANS	2
CRITICAL RANGE	591.483

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2036.7	3	C
A			
A	2027.0	3	S

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
MODEL	1	0.00101400	0.00101400	173.8
ERROR	4	0.00002333	0.00000583	PR >
CORRECTED TOTAL	5	0.00103733		0.000

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.977506	0.1020	0.00241523	2.36833333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00101400	173.83	0.0002

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00101400	173.83	0.0002

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=5.8E-06

NUMBER OF MEANS 2
CRITICAL RANGE .00547834

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.381333	3	C
B	2.355333	3	S

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	89548.16666667	89548.16666667	2.65
OR	4	135120.66666667	33780.16666667	PR > F
RECTED TOTAL	5	224668.83333333		0.1788

QUARE	C.V.	ROOT MSE	STABILIT MEAN
98579	8.8369	183.79381564	2079.83333333

RCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	89548.16666667	2.65	0.1788

RCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	89548.16666667	2.65	0.1788

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=33780.2

NUMBER OF MEANS 2
CRITICAL RANGE 416.89

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2202.0	3	S
A			
A	1957.7	3	C

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 11:58 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.00487350	0.00487350	31.
ERROR	4	0.00061733	0.00015433	PR >
CORRECTED TOTAL	5	0.00549083		0.00

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.887570	0.5332	0.01242310	2.32983333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00487350	31.58	0.0049

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00487350	31.58	0.0049

SAS 11:58 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=1.5E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0281787

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.35833	3	C
B	2.30133	3	S

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	252560.16666667	252560.16666667	3.05
OR	4	330954.66666667	82738.66666667	PR > F
RECTED TOTAL	5	583514.83333333		0.1555

QUARE	C.V.	ROOT MSE	STABILIT MEAN
32826	13.9893	287.64329762	2056.16666667

JRCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	252560.16666667	3.05	0.1555

JRCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	252560.16666667	3.05	0.1555

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=82738.7

NUMBER OF MEANS	2
CRITICAL RANGE	652.446

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2261.3	3	C
A			
A	1851.0	3	S

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 11:58 TUESDAY, MARCH 13, 1990

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VA
MODEL	1	0.01118017	0.01118017	274
ERROR	4	0.00016267	0.00004067	PR
CORRECTED TOTAL	5	0.01134283		0.0

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.985659	0.2732	0.00637704	2.33416667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.01118017	274.92	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.01118017	274.92	0.0001

SAS 11:58 TUESDAY, MARCH 13, 1990

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=4.1E-05

NUMBER OF MEANS 2
CRITICAL RANGE 0.0144647

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.377333	3	C
B	2.291000	3	S

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	1307600.16666667	1307600.16666667	13.75
OR	4	380490.66666667	95122.66666667	PR > F
RECTED TOTAL	5	1688090.83333333		0.0207

QUARE	C.V.	ROOT MSE	STABILIT MEAN
74603	15.7504	308.41962756	1958.16666667

JRCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	1307600.16666667	13.75	0.0207

JRCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	1307600.16666667	13.75	0.0207

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=95122.7

NUMBER OF MEANS	2
CRITICAL RANGE	699.572

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2425.0	3	C
B	1491.3	3	S

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 11:58 TUESDAY, MARCH 13, 1990

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.01144067	0.01144067	46.
ERROR	4	0.00098733	0.00024683	PR >
CORRECTED TOTAL	5	0.01242800		0.00

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.920556	0.6691	0.01571093	2.34800000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.01144067	46.35	0.0024

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.01144067	46.35	0.0024

SAS 11:58 TUESDAY, MARCH 13, 1990 1

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=2.5E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0356363

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.39167	3	C
B	2.30433	3	S

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

PENDENT VARIABLE: STABILIT

URCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
DEL	1	1783240.16666667	1783240.16666667	38.00
ROR	4	187688.66666667	46922.16666667	PR > F
RRECTED TOTAL	5	1970928.83333333		0.0035

SQUARE	C.V.	ROOT MSE	STABILIT MEAN
904771	11.1667	216.61525031	1939.83333333

URCE	DF	TYPE I SS	F VALUE	PR > F
GGREGAT	1	1783240.16666667	38.00	0.0035

URCE	DF	TYPE III SS	F VALUE	PR > F
GGREGAT	1	1783240.16666667	38.00	0.0035

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=46922.2

NUMBER OF MEANS	2
CRITICAL RANGE	491.337

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2485.0	3	C
B	1394.7	3	S

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.00481667	0.00481667	27.:
ERROR	4	0.00070933	0.00017733	PR >
CORRECTED TOTAL	5	0.00552600		0.006

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.871637	0.5655	0.01331666	2.35500000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00481667	27.16	0.0065

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00481667	27.16	0.0065

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=1.8E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0302055

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.38333	3	C
B	2.32667	3	S

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

:NDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	169344.00000000	169344.00000000	6.18
OR	4	109628.00000000	27407.00000000	PR > F
RECTED TOTAL	5	278972.00000000		0.0678

QUARE	C.V.	ROOT MSE	STABILIT MEAN
.07029	7.2930	165.55059650	2270.00000000

JRCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	169344.00000000	6.18	0.0678

JRCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	169344.00000000	6.18	0.0678

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=27407

NUMBER OF MEANS	2
CRITICAL RANGE	375.51

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2438.0	3	C
A			
A	2102.0	3	S

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.00096267	0.00096267	4.
ERROR	4	0.00083667	0.00020917	PR >
CORRECTED TOTAL	5	0.00179933		0.09

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.535013	0.6133	0.01446260	2.35833333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00096267	4.60	0.0985

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00096267	4.60	0.0985

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=2.1E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0328048

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.37100	3	C
A			
A	2.34567	3	S

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

PENDENT VARIABLE: STABILIT

URCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
DEL	1	62220.16666667	62220.16666667	1.62
ROR	4	153160.66666667	38290.16666667	PR > F
RRECTED TOTAL	5	215380.83333333		0.2714

SQUARE	C.V.	ROOT MSE	STABILIT MEAN
288884	9.2834	195.67873330	2107.83333333

OURCE	DF	TYPE I SS	F VALUE	PR > F
GGREGAT	1	62220.16666667	1.62	0.2714

OURCE	DF	TYPE III SS	F VALUE	PR > F
GGREGAT	1	62220.16666667	1.62	0.2714

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=38290.2

NUMBER OF MEANS 2
CRITICAL RANGE 443.848

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2209.7	3	S
A			
A	2006.0	3	C

SAS 12:00 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

SAS 12:00 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
MODEL	1	0.00470400	0.00470400	9.5
ERROR	4	0.00197333	0.00049333	PR >
CORRECTED TOTAL	5	0.00667733		0.036

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.704473	0.9585	0.02221111	2.31733333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00470400	9.54	0.0366

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00470400	9.54	0.0366

SAS 12:00 TUESDAY, MARCH 13, 1990 4

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=4.9E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0503803

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.34533	3	C
B	2.28933	3	S

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

'ENDENT VARIABLE: STABILIT

JRCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
)EL	1	2.66666667	2.66666667	0.00
ROR	4	450842.66666667	112710.66666667	PR > F
RRECTED TOTAL	5	450845.33333333		0.9964

SQUARE	C.V.	ROOT MSE	STABILIT MEAN
000006	14.5629	335.72409307	2305.33333333

URCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	2.66666667	0.00	0.9964

URCE	DF	TYPE III SS	F VALUE	PR > F
GGREGAT	1	2.66666667	0.00	0.9964

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=112711

NUMBER OF MEANS	2
CRITICAL RANGE	761.506

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2306.0	3	C
A			
A	2304.7	3	S

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 12:00 TUESDAY, MARCH 13, 1990

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	0.00516267	0.00516267	9.
ERROR	4	0.00210933	0.00052733	PR >
CORRECTED TOTAL	5	0.00727200		0.03

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.709938	0.9856	0.02296374	2.33000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00516267	9.79	0.0352

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00516267	9.79	0.0352

SAS 12:00 TUESDAY, MARCH 13, 1990

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=5.3E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0520875

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.35933	3	C
B	2.30067	3	S

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                SAS        12:00 TUESDAY, MARCH 13, 1990   8

              CONTENT=5.5

         GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT
                                                                     F VALUE
RCE                DF      SUM OF SQUARES      MEAN SQUARE
                                                                        0.57
EL                  1      29821.50000000     29821.50000000
                                                                     PR > F
OR                  4     210969.33333333     52742.33333333
                                                                      0.4939
RECTED TOTAL        5     240790.83333333

QUARE            C.V.            ROOT MSE     STABILIT MEAN

.23848        10.2244        229.65699060     2246.16666667

JRCE               DF           TYPE I SS    F VALUE     PR > F

GREGAT              1      29821.50000000       0.57     0.4939

URCE               DF         TYPE III SS    F VALUE     PR > F

GREGAT              1      29821.50000000       0.57     0.4939
```

```
                 SAS        12:00 TUESDAY, MARCH 13, 1990 10

               CONTENT=5.5

         GENERAL LINEAR MODELS PROCEDURE

  STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
  NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
        UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
        NULL HYPOTHESES

             ALPHA=0.05  DF=4  MSE=52742.3

               NUMBER OF MEANS         2
               CRITICAL RANGE    520.919

   MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

      SNK     GROUPING           MEAN      N  AGGREGAT

                     A         2316.7      3  C
                     A
                     A         2175.7      3  S
```

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
MODEL	1	0.00281667	0.00281667	46.3
ERROR	4	0.00024333	0.00006083	PR >
CORRECTED TOTAL	5	0.00306000		0.002

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.920479	0.3330	0.00779957	2.34200000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00281667	46.30	0.0024

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00281667	46.30	0.0024

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=6.1E-05

NUMBER OF MEANS 2
CRITICAL RANGE 0.0176914

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.363667	3	C
B	2.320333	3	S

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

PENDENT VARIABLE: STABILIT

URCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
DEL	1	400.16666667	400.16666667	0.01
ROR	4	319427.33333333	79856.83333333	PR > F
RRECTED TOTAL	5	319827.50000000		0.9470

SQUARE	C.V.	ROOT MSE	STABILIT MEAN
001251	12.4681	282.58951384	2266.50000000

URCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	400.16666667	0.01	0.9470

URCE	DF	TYPE III SS	F VALUE	PR > F
GGREGAT	1	400.16666667	0.01	0.9470

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=79856.8

NUMBER OF MEANS	2
CRITICAL RANGE	640.983

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2274.7	3	S
A			
A	2258.3	3	C

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

SAS 12:00 TUESDAY, MARCH 13, 1990 1

KRATON 6/ CENEX

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
MODEL	1	0.00256267	0.00256267	76.8
ERROR	4	0.00013333	0.00003333	PR >
CORRECTED TOTAL	5	0.00269600		0.000

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.950544	0.2457	0.00577350	2.35000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00256267	76.88	0.0009

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00256267	76.88	0.0009

SAS 12:00 TUESDAY, MARCH 13, 1990 19

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=3.3E-05

NUMBER OF MEANS 2
CRITICAL RANGE 0.0130957

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.370667	3	C
B	2.329333	3	S

SAS 12:00 TUESDAY, MARCH 13, 1990 18

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: STABILIT

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	18150.00000000	18150.00000000	0.35
OR	4	207829.33333333	51957.33333333	PR > F
RECTED TOTAL	5	225979.33333333		0.5863

QUARE	C.V.	ROOT MSE	STABILIT MEAN
80317	10.0341	227.94151297	2271.66666667

JRCE	DF	TYPE I SS	F VALUE	PR > F
GREGAT	1	18150.00000000	0.35	0.5863

URCE	DF	TYPE III SS	F VALUE	PR > F
GREGAT	1	18150.00000000	0.35	0.5863

SAS 12:00 TUESDAY, MARCH 13, 1990 20

KRATON 6%-CENEX

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=51957.3

NUMBER OF MEANS	2
CRITICAL RANGE	517.028

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2326.7	3	S
A			
A	2216.7	3	C

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AGGREGAT	2	C S

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: DENSITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
MODEL	1	0.00035267	0.00035267	8.2
ERROR	4	0.00017067	0.00004267	PR >
CORRECTED TOTAL	5	0.00052333		0.045

R-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
0.673885	0.2778	0.00653197	2.35133333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
AGGREGAT	1	0.00035267	8.27	0.0452

SOURCE	DF	TYPE III SS	F VALUE	PR > F
AGGREGAT	1	0.00035267	8.27	0.0452

CONTENT=7

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=4.3E-05

NUMBER OF MEANS 2
CRITICAL RANGE 0.0148161

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	AGGREGAT
A	2.359000	3	C
B	2.343667	3	S

Experimental Design

One Way ANOVA Analysis

for

Unmodified Cenex ane Conoco with 50 and 75 Blows

by

Percent of Asphalt Content

```
OPTION LS=80;
DATA ASPHALT;
LENGTH TEMP TYPE $ 10;
INFILE ASPHALT;
INPUT BLOW AGGREGAT $ TEMP $ TYPE $ CONTENT SAMPLE STABILIT DENSITY;
IF TYPE="Cenex" AND TEMP="Specified" AND AGGREGAT="S";
PROC SORT; BY CONTENT;
PROC GLM; BY CONTENT;
CLASS BLOW;
MODEL DENSITY STABILIT=BLOW;
MEANS BLOW/SNK;
```

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

PNDENT VARIABLE: DENSITY

UCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
DL	1	0.00345600	0.00345600	39.27
PR	4	0.00035200	0.00008800	PR > F
RECTED TOTAL	5	0.00380800		0.0033

-QUARE	C.V.	ROOT MSE	DENSITY MEAN
.07563	0.4042	0.00938083	2.32100000

RCE	DF	TYPE I SS	F VALUE	PR > F
LW	1	0.00345600	39.27	0.0033

RCE	DF	TYPE III SS	F VALUE	PR > F
LW	1	0.00345600	39.27	0.0033

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=8.8E-05

NUMBER OF MEANS	2
CRITICAL RANGE	0.0212781

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.345000	3	75
B	2.297000	3	50

CONTENT=5 CANEX

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	427734.00000000	427734.00000000	96.86
ERROR	4	17664.00000000	4416.00000000	PR > F
CORRECTED TOTAL	5	445398.00000000		0.0006

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.960341	3.5555	66.45299090	1869.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	427734.00000000	96.86	0.0006

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	427734.00000000	96.86	0.0006

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=4416

NUMBER OF MEANS	2
CRITICAL RANGE	150.732

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2136.00	3	75
B	1602.00	3	50

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

[DEPE]NDENT VARIABLE: DENSITY

[SO]U[R]CE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
[MO]DEL	1	0.00050417	0.00050417	0.83
[ER]ROR	4	0.00242067	0.00060517	PR > F
[C]ORRECTED TOTAL	5	0.00292483		0.4130

[R]-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
[0].172374	1.0566	0.02460014	2.32816667

[SOU]RCE	DF	TYPE I SS	F VALUE	PR > F
[BLO]W	1	0.00050417	0.83	0.4130

[SOU]RCE	DF	TYPE III SS	F VALUE	PR > F
	1	0.00050417	0.83	0.4130

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=6.1E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0557992

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.33733	3	75
A			
A	2.31900	3	50

CONTENT=5.5 CENEX

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	350900.16666667	350900.16666667	57.90
ERROR	4	24243.33333333	6060.83333333	PR > F
CORRECTED TOTAL	5	375143.50000000		0.0016

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.935376	3.5835	77.85135409	2172.50000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	350900.16666667	57.90	0.0016

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	350900.16666667	57.90	0.0016

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=6060.83

NUMBER OF MEANS	2
CRITICAL RANGE	176.586

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2414.33	3	75
B	1930.67	3	50

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

ENDENT VARIABLE: DENSITY

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	0.00252150	0.00252150	7.42
OR	4	0.00135933	0.00033983	PR > F
RECTED TOTAL	5	0.00388083		0.0528

SQUARE	C.V.	ROOT MSE	DENSITY MEAN
549732	0.7909	0.01843457	2.33083333

URCE	DF	TYPE I SS	F VALUE	PR > F
OW	1	0.00252150	7.42	0.0528

URCE	DF	TYPE III SS	F VALUE	PR > F
OW	1	0.00252150	7.42	0.0528

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=3.4E-04

NUMBER OF MEANS	2
CRITICAL RANGE	0.0418142

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.35133	3	75
A			
A	2.31033	3	50

CONTENT=6 CHILL

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	582193.50000000	582193.50000000	3.32
ERROR	4	700390.00000000	175097.50000000	PR > F
CORRECTED TOTAL	5	1282583.50000000		0.1423

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.453922	19.5035	418.44653183	2145.50000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	582193.50000000	3.32	0.1423

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	582193.50000000	3.32	0.1423

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=175098

NUMBER OF MEANS	2
CRITICAL RANGE	949.141

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2457.0	3	75
A			
A	1834.0	3	50

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

NDENT VARIABLE: DENSITY

RCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
EL	1	0.00187267	0.00187267	38.88
OR	4	0.00019267	0.00004817	PR > F
RECTED TOTAL	5	0.00206533		0.0034

QUARE	C.V.	ROOT MSE	DENSITY MEAN
.06714	0.2936	0.00694022	2.36366667

RCE	DF	TYPE I SS	F VALUE	PR > F
W	1	0.00187267	38.88	0.0034

RCE	DF	TYPE III SS	F VALUE	PR > F
W	1	0.00187267	38.88	0.0034

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=4.8E-05

NUMBER OF MEANS	2
CRITICAL RANGE	0.0157421

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.381333	3	75
B	2.346000	3	50

CONTENT=6.5 CELLA

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	126150.00000000	126150.00000000	3.06
ERROR	4	165048.00000000	41262.00000000	PR > F
CORRECTED TOTAL	5	291198.00000000		0.1553

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.433210	9.3522	203.13049993	2172.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	126150.00000000	3.06	0.1553

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	126150.00000000	3.06	0.1553

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=41262

NUMBER OF MEANS 2
CRITICAL RANGE 460.75

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2317.0	3	75
A			
A	2027.0	3	50

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=5 *CONCD*

GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: DENSITY

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
ODEL	1	0.00459267	0.00459267	26.91
RROR	4	0.00068267	0.00017067	PR > F
ORRECTED TOTAL	5	0.00527533		0.0066

-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
).870593	0.5621	0.01306395	2.32433333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	0.00459267	26.91	0.0066

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	0.00459267	26.91	0.0066

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=1.7E-04

NUMBER OF MEANS 2
CRITICAL RANGE 0.0296323

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.35200	3	75
B	2.29667	3	50

SAS 11:50 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	474328.16666667	474328.16666667	12.
ERROR	4	156600.66666667	39150.16666667	PR >
CORRECTED TOTAL	5	630928.83333333		0.02

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.751793	10.3332	197.86401054	1914.83333333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	474328.16666667	12.12	0.0253

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	474328.16666667	12.12	0.0253

SAS 11:50 TUESDAY, MARCH 13, 1990

CONTENT=5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=39150.2

NUMBER OF MEANS 2
CRITICAL RANGE 448.805

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2196.0	3	75
B	1633.7	3	50

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: DENSITY

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
ODEL	1	0.00390150	0.00390150	42.25
RROR	4	0.00036933	0.00009233	PR > F
ORRECTED TOTAL	5	0.00427083		0.0029

-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
.913522	0.4081	0.00960902	2.35483333

OURCE	DF	TYPE I SS	F VALUE	PR > F
LOW	1	0.00390150	42.25	0.0029

OURCE	DF	TYPE III SS	F VALUE	PR > F
LOW	1	0.00390150	42.25	0.0029

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=9.2E-05

NUMBER OF MEANS 2
CRITICAL RANGE 0.0217957

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.380333	3	75
B	2.329333	3	50

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALU
MODEL	1	838508.16666667	838508.16666667	17.6
ERROR	4	190334.66666667	47583.66666667	PR >
CORRECTED TOTAL	5	1028842.83333333		0.013

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.815001	10.7766	218.13680723	2024.16666667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	838508.16666667	17.62	0.0137

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	838508.16666667	17.62	0.0137

CONTENT=5.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=47583.7

NUMBER OF MEANS	2
CRITICAL RANGE	494.788

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2398.0	3	75
B	1650.3	3	50

```
GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS        LEVELS     VALUES

BLOW            2       50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6
```

```
                 SAS        11:50 TUESDAY, MARCH 13, 1990 16

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: DENSITY

OURCE              DF     SUM OF SQUARES        MEAN SQUARE       F VALUE

ODEL                1         0.00350417         0.00350417          8.54

RROR                4         0.00164067         0.00041017        PR > F

ORRECTED TOTAL      5         0.00514483                           0.0431

-SQUARE          C.V.           ROOT MSE       DENSITY MEAN

.681104        0.8553         0.02025257         2.36783333

SOURCE             DF        TYPE I SS    F VALUE     PR > F

BLOW                1       0.00350417       8.54     0.0431

SOURCE             DF      TYPE III SS    F VALUE     PR > F

BLOW                1       0.00350417       8.54     0.0431
```

```
                 SAS        11:50 TUESDAY, MARCH 13, 1990 18

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
      UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL
      NULL HYPOTHESES

ALPHA=0.05  DF=4  MSE=4.1E-04

NUMBER OF MEANS          2
CRITICAL RANGE   0.0459379

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK      GROUPING            MEAN      N  BLOW

                A         2.39200      3  75

                B         2.34367      3  50
```

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VAL
MODEL	1	124128.16666667	124128.16666667	2..
ERROR	4	201464.66666667	50366.16666667	PR >
CORRECTED TOTAL	5	325592.83333333		0.19:

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.381237	11.1331	224.42407773	2015.83333333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	124128.16666667	2.46	0.1915

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	124128.16666667	2.46	0.1915

CONTENT=6

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=50366.2

NUMBER OF MEANS	2
CRITICAL RANGE	509.05

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2159.7	3	75
A			
A	1872.0	3	50

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOW	2	50 75

NUMBER OF OBSERVATIONS IN BY GROUP = 6

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: DENSITY

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
ODEL	1	0.00187267	0.00187267	18.12
RROR	4	0.00041333	0.00010333	PR > F
ORRECTED TOTAL	5	0.00228600		0.0131

-SQUARE	C.V.	ROOT MSE	DENSITY MEAN
.819189	0.4296	0.01016530	2.36600000

OURCE	DF	TYPE I SS	F VALUE	PR > F
LOW	1	0.00187267	18.12	0.0131

OURCE	DF	TYPE III SS	F VALUE	PR > F
LOW	1	0.00187267	18.12	0.0131

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: DENSITY
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=1.0E-04

NUMBER OF MEANS	2
CRITICAL RANGE	0.0230574

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	2.383667	3	75
B	2.348333	3	50

SAS 11:50 TUESDAY, MARCH 13, 1990 22

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STABILIT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	429872.66666667	429872.66666667	4.45
ERROR	4	386127.33333333	96531.83333333	PR > F
CORRECTED TOTAL	5	816000.00000000		0.1025

R-SQUARE	C.V.	ROOT MSE	STABILIT MEAN
0.526805	19.1197	310.69572468	1625.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
BLOW	1	429872.66666667	4.45	0.1025

SOURCE	DF	TYPE III SS	F VALUE	PR > F
BLOW	1	429872.66666667	4.45	0.1025

SAS 11:50 TUESDAY, MARCH 13, 1990 24

CONTENT=6.5

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STABILIT
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=0.05 DF=4 MSE=96531.8

NUMBER OF MEANS	2
CRITICAL RANGE	704.735

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	BLOW
A	1892.7	3	75
A			
A	1357.3	3	50